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CALCIUM AND ZINC IN PARAKERATOSIS OF SWINE [1]

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Michigan State University

THE results to be presented in this study represent a continuation of recently reported work on the effects of high levels of calcium and phosphorus on the incidence of swine parakeratosis and its prevention by supplemental zinc (Luecke *et al.*, 1956). In the previously reported work two basal rations were used, both of which contained considerably more calcium and phosphorus than is recommended by the National Research Council (1953). Furthermore, the Ca to P ratios of the two basal rations were quite different. In view of this it was decided that in the first experiment to be reported in this paper an attempt would be made to keep the Ca to P ratios more nearly alike, and also that one of the rations to be used would be more closely in agreement with the recommendations of the National Research Council (1953).

In the second experiment, two levels of limestone were studied to determine the effect of increased calcium on growth, feed conversion and incidence of parakeratosis. In addition to the growth studies, serum alkaline phosphatase determinations were carried out on all of the pigs in the second experiment.

Experimental

As stated previously the data contained in this paper are the result of two experiments. Trial I was conducted during the summer of 1955 and trial II during the following winter. In each trial weanling pigs 6 to 7 weeks of age were used. All animals were sprayed for mange with lindane, wormed, and vaccinated for hog cholera at the start of the trial; and were self-fed the various rations in pens with concrete floors.

The basal rations used in both trials are shown in table 1. The crude protein, calcium, phosphorus and zinc determinations were carried out by the A.O.A.C. methods (1955).

In comparing rations A and B used in trial I it should be noted that

[1] Published with the approval of the Director of the Michigan Agricultural Experiment Station as Journal Article No. 1940.

[2] Departments of Agricultural Chemistry, Animal Husbandry and Animal Pathology, East Lansing. The authors are indebted to the American Cyanamid Co., Pearl River, N. Y. for the Aurofac, and to Merck and Co., Inc., Rahway, New Jersey for the B vitamin supplement used in the experiments.

TABLE 1. COMPOSITION OF BASAL RATIONS TOGETHER WITH RELEVANT CHEMICAL ANALYSES[a]

	Trial I		Trial II		
	A	B	C	D	E
	%	%	%	%	%
Corn	75.9	72.9	80.5	78.5	75.5
Soybean oil meal	20.0	21.0	12.0	12.0	13.0
Fish meal[b]	2.0	2.0			
Meat and bone scrap			4.0	4.0	4.0
Dehydrated alfalfa			2.5	2.5	2.5
Dicalcium phosphate	0.5	2.5	0.5	0.5	0.5
Limestone	1.1	1.1		2.0	4.0
Trace mineralized salt[c]	0.5	0.5	0.5	0.5	0.5
Crude protein, %	17.6	17.5	15.8	15.6	15.4
Calcium, %	0.65	1.25	0.51	1.21	1.90
Phosphorus, %	0.53	0.95	0.61	0.61	0.61
Zinc, p.p.m.	45	40	32	29	31

[a] All rations were supplemented with 2500 I.U. of vitamin A per lb. and 250 I.U. of vitamin D per lb. In addition, all rations were supplemented with chlortetracycline at the rate of 20 gm. per ton, and a B vitamin supplement (Merck's No. 58C) at the rate of 2 lb. per ton.

[b] The fish meal was a Menhaden meal containing 6% protein and between 5 and 8% of fat.

[c] The trace mineralized salt had the following composition (in percent): sodium chloride, 98.5 to 99.5; iodine, 0.007; iron, 0.09; manganese, 0.16; copper, 0.05; cobalt, 0.01 and zinc, 0.005.

ration A contains a considerably lower level of calcium and phosphorus than does ration B. However, the Ca to P ratios are fairly close being 1.2 to 1 for ration A and 1.3 to 1 for ration B.

In trial II where rations C, D and E were used (table 1) the main variant was the calcium content brought about by the addition of 2% of limestone in ration D and of 4% in ration E.

TABLE 2. RESULTS OF TRIAL I

(Ten pigs per lot on trial for nine weeks)

Lot. no.	Ration and supplement	Av. initial wt.	Av. daily gain	Av. feed per lb. gain	Av. no. with dermatosis
		lb.	lb.	lb.	
1	A	32.1	1.22	3.10	1
2	A+Zn[a]	32.4	1.30	2.97	0
3	B	32.2	0.75	3.66	10
4	B+Zn[a]	32.3	1.25	3.01	0

[a] Fed 50 p.p.m. of zinc as zinc carbonate.

Results and Discussion

Trial I

The more important results of trial I are presented in table 2. In the case of the pigs in lot 1, nine of the animals showed normal gains, but one animal developed severe parakeratosis during the seventh week and was losing weight at the conclusion of the experiment. The somewhat lower average daily gain of the pigs in lot 1 as compared with the performance of the animals in lot 2 fed supplemental zinc (as zinc carbonate) was due solely to the one animal which developed parakeratosis.

The performance of the pigs in lot 3 fed the high calcium and phosphorus ration B was very poor (table 2). In this group, parakeratosis developed in all animals between the sixth and eighth week, and nine of the ten animals were severely affected with the disease. The supplementation of ration B with 50 p.p.m. of zinc (lot 4) completely counteracted the deleterious effects of the high mineral level and allowed for normal gains and feed conversion. No indications of even mild symptoms of parakeratosis were noted in this group.

The average growth performance of the pigs in lots 3 and 4 during the course of the experiment is presented in figure 1. The average daily gains of both lots were essentially the same for the first 4 weeks. From this point on, however, the average daily gain of the pigs in lot 3 gradually decreased to a low of only 0.13 lb. per day between the eighth and ninth week. At this point it was decided to attempt zinc therapy with the animals in this lot. Accordingly, the feed was removed from the self-feeder, 500 p.p.m. of zinc added (as zinc carbonate), mixed and returned to the feeder, within 24 hours a very marked improvement in appetite was noted, and as indicated in figure 1 the average daily gain of the pigs increased to 1.68 lb. during the two weeks of therapy. As might be expected, there was also a very marked improvement in feed efficiency. The disappearance of the skin lesions as a result of zinc therapy was gradual and required as long as 6 weeks in some cases.

The results of trial I indicate that a high Ca to P ratio is not necessary to produce growth depression and parakeratosis since the Ca to P ratios of both rations A and B were of the same order of magnitude. Moreover, the fact that one animal fed ration A exhibited severe symptoms of parakeratosis indicates that the feeding of a lower calcium level does not always protect against the disease.

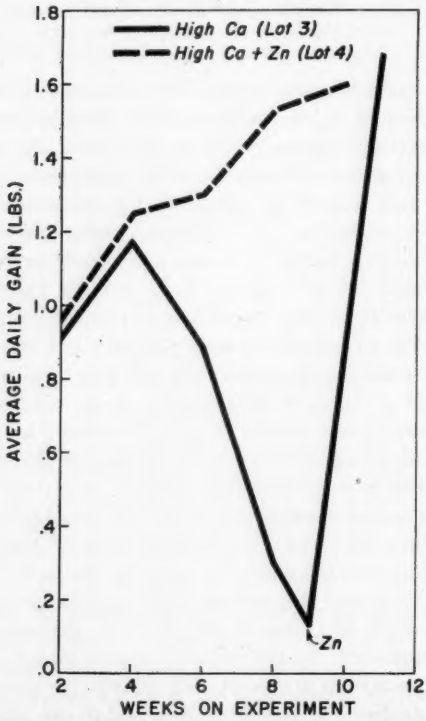

Figure 1. Average daily gains of pigs in lots 3 and 4 fed ration B, and also the response of the animals in lot 3 to zinc therapy started at the end of the ninth week.

Trial II

Trial II was undertaken in an effort to determine the effect of increasing increments of limestone on growth, feed conversion and incidence of parakeratosis. The major results of this experiment are presented in table 3. The results obtained with the animals in lot 1 fed basal ration C were surprising. Since ration C contained a relatively low level of calcium, it might be expected that, based on the results of trial I, reasonably good growth performance would be obtained. However, the results were quite to the contrary. The average daily gain and feed conversion of the pigs in this lot were very poor. In addition, during the fourth week of the experiment, four of the animals in lot 1

showed symptoms of parakeratosis. Perhaps of equal importance was the fact that the six remaining pigs in lot 1 which did not have any skin lesions also showed a growth depression. The performance of the pigs in lot 2 indicates that the deleterious effects of ration C were completely counteracted by the addition of 50 p.p.m. of zinc.

The performance of the pigs in lot 3 fed ration D containing 2% of limestone was extremely poor as shown in table 3. As an example of the severity of the growth depression produced by the feeding of ration D, the average daily gain of this group was only 0.08 lb. between the

TABLE 3. RESULTS OF TRIAL II

(Ten pigs per lot on trial for eight weeks)

Lot. no.	Ration and supplement	Av. initial wt.	Av. daily gain	Av. feed per lb. gain	Av. no. with dermatosis
		lb.	lb.	lb.	
1	C	29.2	0.59	4.20	4
2	C+Zn[a]	29.3	1.23	3.18	0
3	D	29.3	0.21	7.47	10
4	D+Zn[a]	29.2	1.16	3.50	0
5	E	29.2	0.17	9.28	10
6	E+Zn[a]	29.3	0.98	3.97	0

[a] Fed 50 p.p.m. of zinc as zinc carbonate.

fourth and sixth week of the experiment. Very severe symptoms of parakeratosis developed in all pigs of lot 3 during the third week of the trial.

Pigs in lot 4 fed the zinc-supplemented ration D showed a five fold increase in average daily gain over the group fed the unsupplemented ration. A very marked improvement in feed conversion was also observed (table 3). It should be noted, however, that the pigs in lot 4 were not as efficient in converting feed to body weight gain as were the animals in lot 2 fed the zinc supplemented ration C.

The feeding of ration E, containing 4% of limestone, to the pigs in lot 5 produced severe growth depression, lowered appetite and a 100% incidence of parakeratosis. The effects produced by feeding ration E were much the same as that produced by feeding the unsupplemented ration D (lot 3) with respect to average daily gain, feed conversion and severity of the parakeratosis produced as well as the time of onset of the disease.

No incidence of parakeratosis was observed in the lot 6 pigs fed

ration E supplemented with zinc (table 3), and over a five fold increase in average daily gain was made by this group when compared with the gain made by the pigs in lot 5. Although there was a marked improvement in feed conversion brought about by zinc supplementation of ration E, the feed efficiency of the pigs in lot 6 was still poor. The reason for this is not apparent. It may be that the excessive amount of limestone in ration D had a marked effect on palatability. However, other factors may have been involved. In this connection, Steenbock and Herting (1955) have observed in the rat that when the dietary Ca to P ratio was increased to approximately 4.5 to 1.0 the addition of vitamin D depressed growth. In the present experiment the Ca to P ratio of ration E was approximately 3 to 1.

In order to verify the presence or absence of parasites, skin biopsies were made on five of the pigs severely affected with parakeratosis—two animals each from lots 1 and 3 and one from lot 5. Sections of skin were taken from the posterior abdominal region in the area of the groin. The specimens were placed in 10% formalin, dehydrated and embedded in paraffin in the usual manner. Serial sections, cut at 12 microns, were made of each, stained with hematoxylin and eosin and examined. The stratum corneum was thickened and in places masses of nuclei were noted within the stratum corneum. There was also an increase in number and length of the dermal papillae. However, no evidence of mites or other parasites was noted.

At the end of the eighth experimental week of trial II the pigs in lots 1, 3 and 5 were fed their respective rations supplemented with 500 p.p.m. of zinc. Again, as in trial I the results of zinc therapy were very marked, and during the subsequent 4 weeks of treatment the average daily gains of lots 1, 3 and 5 were 1.67, 1.49 and 1.01 lb. respectively. The growth response to zinc therapy of the pigs in lot 5 was not as great as the response of lots 1 and 3, indicating the possibility of factors other than zinc being involved in the high limestone ration E even though zinc therapy did clear up the skin condition.

In addition to the growth performance data obtained in trial II studies were made on the serum alkaline phosphatase activities of all animals. Although the role of alkaline phosphatase in metabolism is not clearly understood, it is known to be involved in bone formation and, in addition, believed to participate in the transport of glucose across the intestinal epithelium and in protein synthesis. However, the main reason for undertaking a study of serum alkaline phosphatase activities in trial II was based on the recent work of Hofstee (1955).

This investigator has postulated that alkaline phosphatase consists of an enzyme-zinc complex associated with a nondialyzable coenzyme.

As far as the authors are aware there is no published information on normal serum alkaline phosphatase activity levels in the weanling pig. Young and Underdahl (1948) have studied the activities of this enzyme in the suckling pig from 0 to 56 days of age. They found that the activities were very high at birth but leveled off at around 28 days of age.

In the present experiment the method of Bodansky (1933) was used for all determinations. Blood samples were obtained from all pigs in trial II during the seventh week. The mean values and standard errors for serum alkaline phosphatase, expressed in Bodansky units per 100 ml. of serum, for lots 1 through 6 were: $1.19 \pm .33$, $2.48 \pm .42$, $0.80 \pm .19$, $2.72 \pm .28$, $0.65 \pm .14$ and 5.84 ± 1.15. The results of these determinations seem to indicate that the animals in lots 3 and 5 which were severely affected with parakeratosis also had the lowest average serum alkaline phosphatase activities.

In addition to the above values, the effect of zinc therapy on serum alkaline phosphatase activities of pigs in lots 1, 3 and 5 was also studied. As stated previously, at the end of the eighth experimental week the pigs in these three lots were fed their respective rations plus 500 p.p.m. of zinc. After two weeks of therapy serum alkaline phosphatase determinations were again made on all pigs of the three lots. The mean values expressed in Bodansky units per 100 ml. of serum for lots 1, 3 and 5 were $4.03 \pm .38$, $4.58 \pm .31$ and $6.18 \pm .89$ respectively. These values represent a very marked increase over that obtained with the same animals before zinc therapy. While these studies of the effect of zinc on serum alkaline phosphatase activity in the pig must certainly be considered as preliminary, they may eventually shed some light on the metabolic defects associated with the feeding of high levels of dietary calcium and also on the beneficial role played by zinc in correcting the condition.

The results of trial II indicated that excessive calcium has a very deleterious effect on growth and feed conversion as well as being a predisposing factor in the incidence of parakeratosis, and furthermore that supplementary zinc can, in the main, counteract these effects. The poor growth and relatively high (40%) incidence of parakeratosis produced by feeding the unsupplemented ration C in trial II compared with the good growth and relatively low (10%) incidence of dermatosis produced by feeding the unsupplemented ration A in trial I is certainly

an indication that the use of lower levels of calcium in the ration will not necessarily prevent the disease from occurring. Moreover, whether these growth differences could be explained by variations in body stores of zinc between animals used in trial I and trial II is not known; however, Underwood (1956) has indicated that an appreciable proportion of body zinc is stored in the bones. The fact that ration A contained 45 p.p.m. of zinc while ration C contained only 32 p.p.m. of zinc may have also been a factor causing the poorer growth of the animals fed the latter ration.

The poor growth exhibited by those pigs which did not develop symptoms of parakeratosis in lot 1 of the second trial is interesting in view of the findings of Stirn *et al.* (1935) with the zinc deficient rat. These workers found that zinc deficiency resulted in almost complete growth failure even though food consumption was reduced only moderately. This would seem to indicate that zinc is a rather specific element for growth.

The results presented in this paper indicate the desirability of zinc supplementation in practical swine feeding, at least for the growing pig. Furthermore, since many manufactured supplements contain 3.5 to 5.0% of calcium, it is apparent that when these supplements are used to make a mixed ration for weanling pigs the total calcium content of the ration may be from 0.8 to 1.0%. Parakeratosis sometimes develops on rations containing 0.6 to 0.7% of calcium and in our experience it develops very consistently whenever the ration approaches 1.0% in calcium. Since the individual nutrient requirements of the animal change at varying rates as the animal grows, the desirability of using the protein supplement as a carrier of all supplemental nutrients, i.e. protein, vitamins, minerals, antibiotics, etc., is open to question. However, at the present time it appears that the addition of 50 p.p.m. of zinc is a practical way of eliminating some of the deleterious effects due to feeding excess calcium.

Summary

The data contained in this paper are a result of two separate experiments involving a total of 10 lots of 10 pigs each. In the first trial the feeding of a ration containing 0.65% calcium and 0.53% phosphorus resulted in good growth; however, a 10% incidence of parakeratosis was noted. The feeding of a ration containing 1.25% calcium and 0.95%

phosphorus resulted in very poor growth and a 100% incidence of parakeratosis.

In the second trial the feeding of a ration containing 0.51% calcium and 0.61% phosphorus resulted in depressed growth and a 40% incidence of parakeratosis. In addition, rations containing 1.21% calcium and 1.90% calcium both with 0.61% phosphorus resulted in severely depressed growth and a 100% incidence of parakeratosis.

In both trials the supplementation of all rations with 50 p.p.m. of zinc (as zinc carbonate) markedly increased growth rate, improved feed efficiency and completely prevented symptoms of parakeratosis.

In all cases symptoms of parakeratosis were alleviated by zinc therapy.

In the second trial, preliminary studies indicated that dietary zinc increased serum alkaline phosphatase activity.

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THE VALUE OF SOYBEAN OIL MEAL, LOW GOSSYPOL (DE-GOSSYPOLIZED) SOLVENT PROCESSED COTTONSEED MEAL, LOW GOSSYPOL EXPELLER PROCESSED COTTONSEED MEAL, AND VARIOUS BLENDS THEREOF IN THE RATION OF GROWING-FATTENING SWINE [1]

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Florida Agricultural Experiment Station [2]

THE presence of toxic levels of gossypol in ordinarily processed cottonseed meal precludes its unlimited use as a protein supplement in swine and poultry feeds. During the past few years, numerous workers have devoted much effort toward the production of cottonseed meal which is low enough in gossypol to be used successfully in unrestricted amounts for swine and poultry. Much progress has been made. In view of the ever-present shortage of proteinaceous feedstuffs for swine, the importance of this development to swine producers, particularly in the South, is apparent. However, it should be pointed out that the problem has involved more than just gossypol. Dermatosis, or parakeratosis as observed by Dyer *et al.* (1951, 1952) and Wallace *et al.* (1955) has been a complicating factor. The recent finding by Tucker *et al.* (1955) that zinc would prevent parakeratosis has paved the way for a more critical appraisal of the protein quality of low gossypol cottonseed meals.

This study was undertaken to determine the usefulness of two differently processed cottonseed meals low in free-gossypol (.01%) as sources of protein for the weanling pig fed in dry lot. It was desired to determine to what extent each meal could satisfactorily replace a good quality soybean oil meal and to observe possible complimentary effects when the cottonseed meals were fed in combination with soybean oil meal.

The experiment was also designed to provide information on the supplemental effect of procaine penicillin vs. procaine penicillin and erythromycin in combination.

[1] Florida Agricultural Experiment Station Journal Series No. 508.
[2] Department of Animal Husbandry and Nutrition, Gainesville. This study was supported in part by a grant from the Eli Lily Company, Indianapolis, Indiana.

Experimental Procedure

Animals

All pigs used in the test were weaned off pasture at eight weeks of age and started on the experiment at approximately nine weeks of age. Seventy-two pigs of Duroc, Hampshire, and Spotted Poland China breeding were involved in the test. The pigs were divided according to breed, initial weight and previous treatment, into nine experimental groups of eight pigs each and each group was sub-divided into two pens of four animals each. The experiment was conducted in concrete pens which were cleaned and washed daily.

TABLE 1. COMPOSITION AND PROCESSING INFORMATION FOR THE EXPERIMENTAL COTTONSEED MEALS [a]

Item determined	Expeller cottonseed meal	Degossypolized cottonseed meal
Protein, %	42.4	45.6
Nitrogen solubility, %	42.2	89.0
Free gossypol, %	0.01	0.01
Total gossypol, %	0.74	0.48
Time cooked or toasted	53 min.	60–90 min.
Temperatures used	247° F.	150°–230° F.
Initial moisture, %	13.0%	13.5%
Final moisture, %	3.0%	9.0%

[a] The meals and processing data were supplied through the courtesy of the Buckeye Cotton Oil Division of the Buckeye Cellulose Corporation, Cincinnati, Ohio.

Experimental Rations

The chemical composition and processing data for the two cottonseed meals involved in the test are shown in table 1.

Nine rations were wormulated as shown in table 2. The soybean oil-meal used was a 44% solvent—extracted meal purchased on the open market and was a good quality meal. It was used as the sole source of supplementary protein in Ration 1. In Rations 2 and 3 the expeller cottonseed meal and solvent (degossypolized) meal served as the sole supplementary protein sources respectively. The other six rations studied consisted of various blends of the soybean oil meal with the two cotton-seed meals. All rations were fortified with vitamins and minerals as shown in table 2.

Procaine penicillin, at the rate of 2.5 mg. per lb. of feed, was added to all nine rations. One-half of the pigs (one lot of four pigs) in each of the nine experimental groups received in addition 2.5 mg. of erythro-

TABLE 2. COMPOSITION OF EXPERIMENTAL RATIONS [a]

Ration number	1	2	3	4	5	6	7	8	9
Ground yellow corn	79.00	76.50	78.00	78.00	78.50	78.00	79.00	77.00	78.50
Soybean oil meal	19.00			14.50	14.50	9.50	9.50	5.00	4.50
Expeller cottonseed meal		21.50		5.50		10.50		16.00	
Solvent (degossypolized) cottonseed meal			20.00		5.00		9.50		15.00
Ground limestone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Steamed bone meal	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt-trace mineral [b]	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Calculated protein, %	16.08	16.01	16.14	16.19	16.19	15.95	15.95	16.07	16.03

[a] Fortified with 2000 I.U. of Vitamin A, 100 mg. Vitamin B^{12} and 452 mg. of Lederle Fortafeed 2–49C per lb. of ration. (The Fortafeed contained not less than 2 gm. of riboflavin, 4 gm. of pantothenic acid, 9 gm. of niacin, 10 gm. of choline chloride and 60 mg. of folic acid per lb.)

[b] The salt-free mineral mixture was composed of: iodized salt, 50 lb.; manganese sulfate, 921 gm.; ferrous sulfate, 398 gm.; copper sulfate, 125 gm.; cobalt carbonate, 10 gm.; and zinc sulfate, 350 gm.

TABLE 3. SUMMARY OF PERFORMANCE OF PIGS FED SOYBEAN OIL MEAL, EXPELLER COTTONSEED MEAL, DEGOSSYPOLIZED SOLVENT COTTONSEED MEAL AND VARIOUS COMBINATIONS THEREOF AS SOURCES OF SUPPLEMENTARY PROTEIN

Ration number	1	2	3	4	5	6	7	8	9
Percent of protein supplements in rations:									
Soybean oil meal (solvent)	19.00			14.50	14.50	9.50	9.50	5.00	4.50
Cottonseed meal (expeller)		21.50		5.50		10.50		16.00	
Cottonseed meal (solvent-degossypolized)			20.00		5.00		9.50		15.00
Number of pigs	8	8	8	8	8	7	8	8	7
Av. initial wt., lb.	32.0	32.1	32.1	31.9	32.0	32.1	32.1	31.9	31.9
Av. final wt., lb.	151.9	130.4	144.5	148.4	154.0	147.3	157.3	145.4	150.3
Av. daily gain, lb.	1.71	1.40	1.61	1.66	1.74	1.64	1.79	1.62	1.71
Av. daily feed consumption, lb.	5.54	5.13	5.43	5.52	5.78	5.61	5.71	5.82	5.61
Feed per lb. gain, lb.	3.23	3.66	3.38	3.31	3.31	3.42	3.19	3.59	3.31
Days on test	70	70	70	70	70	70	70	70	70

TABLE 4. SUMMARY OF PERFORMANCE OF PIGS AS INFLUENCED BY ANTIBIOTIC SUPPLEMENTATION

Antibiotic fed	Penicillin			Penicillin and erythromycin		
Measurement criteria	Av. daily gain lb.	Daily feed consumed	Feed per lb. gain	Av. daily gain lb.	Daily feed consumed	Feed per lb. gain
	lb.	lb.	lb.	lb.	lb.	lb.
Ration 1	1.69	5.27	3.12	1.73	5.80	3.34
Ration 2	1.25	4.63	3.72	1.56	5.62	3.60
Ration 3	1.60	5.35	3.34	1.61	5.50	3.42
Ration 4	1.62	5.26	3.25	1.70	5.76	3.38
Ration 5	1.66	5.40	3.26	1.83	6.16	3.37
Ration 6	1.59	5.46	3.43	1.70	5.80	3.45
Ration 7	1.76	5.69	3.22	1.82	5.73	3.17
Ration 8	1.60	5.61	3.50	1.64	6.03	3.67
Ration 9	1.62	5.57	3.45	1.77	5.63	3.18
Averages	1.60	5.36	3.36	1.71	5.78	3.41

mycin per lb. of feed. Thus, one half of the pigs on each test ration was supplied with only penicillin and the other half received both penicillin and erythromycin.

The rations were self fed and the pigs were on experiment for ten weeks.

Results and Discussion

The experimental results are shown in tables 3 and 4. A summary of the statistical analysis is presented in table 5.

TABLE 5. ANALYSIS OF VARIANCE FOR DAILY GAINS AND FEED EFFICIENCY

Source	d.f.	S.S.	M.S.
	Daily gains		
Total	69	3.1837	0.0461
Ration	8	0.7789	0.0974**
Antibiotic	1	0.2082	0.2082**
Ration×antibiotic	8	1.1302	0.1414**
Type of C.S.M.	1	0.2407	0.2407**
Level of S.O.M.	4	0.4893	0.1223**
Error	52	1.0665	0.0205
	Feed efficiency		
Total	17	5241.5	308.3
Ration	8	4110.6	513.8*
Antibiotic	1	100.9	100.9
Error	8	1029.8	128.7

* Significant at 5% level.
** Significant at 1% level.

At the end of the test period data were available for 70 of the original 72 pigs started on the experiment. One of the pigs was removed from Ration 9 (penicillin only) at the end of two weeks. The pig was afflicted with an unusual condition diagnosed by the attending veterinarian as a reaction to penicillin. Symptoms included extreme skin irritation with marked swelling around face and eyes. The pig rubbed his head and feet until they were raw and bleeding.

No elevation in temperature was noted. This pig finally responded to benadryl and cortisone treatment and made a full recovery. After a three week period, the injection of penicillin failed to confirm the original diagnosis of a sensitivity to penicillin, so it cannot be said with certainty that the penicillin in the ration caused the symptoms observed. The other pig removed from the experiment (Ration 6) suddenly became sick during the eighth week. The cause of illness was not determined.

No cases of parakeratosis were encountered in the experiment. The addition of 12 p.p.m. of zinc as zinc sulfate to all rations may have prevented the syndrome. In previous tests at the Florida Station under similar conditions and involving similar test meals, the incidence of parakeratosis has been quite high when no supplementary zinc was supplied.

Average Daily Gains

The rations containing degossypolized solvent cottonseed meal consistently produced better gains than rations containing comparable amounts of the expeller cottonseed meal. Since the meals contained the same amount of free gossypol, and assuming that bound gossypol would not be a factor, then it would seem that the protein quality of the degossypolized meal was superior to the expeller meal. As indicated in table 1, the nitrogen solubility was 89% for the degossypolized meal and only 42.2% for the expeller meal. Herein may lie the explanation for the observed differences in growth rate.

The poorest gaining pigs in the experiment were those that obtained all of their supplementary protein from the expeller cottonseed meal. However, even these pigs gained 1.40 lb. per head per day which is good performance for pigs from 30 to 150 lb. live weight. When the expeller meal was partially replaced with soybean oil meal (Rations 4, 6 and 8) there was a marked improvement in performance. In no case when expeller cottonseed meal was a part of the ration did the gains excel the gains by pigs on the soybean oil meal control ration.

The animals that were fed degossypolized cottonseed meal as the

only supplementary protein gained an average of 1.61 lb. per day, compared to 1.71 for the soybean meal group. It is interesting to note that when the degossypolized meal was combined with soybean oil meal at the various levels the performance was equal to or better than that of the soybean oil meal alone. Thus it appears that the combination of meals in this case provided a more efficient source of protein.

The results of the antibiotic treatments are summarized in table 4. The combination of erythromycin and penicillin produced significantly greater growth responses than penicillin alone. This improvement was observed for all nine rations. Unfortunately, the design of the experiment prevented the use of a treatment group getting erythromycin only. Without this group it is impossible to say whether the growth improvement was due to a complimentary effect of penicillin and erythromycin or was due entirely to the erythromycin.

Feed Efficiency

The rations containing degossypolized cottonseed meal were more efficiently utilized in producing weight gains than rations containing similar amounts of expeller cottonseed (table 3). The poorest feed conversion occurred with the ration that contained expeller cottonseed meal as the entire supplementary protein. The feed efficiencies of the rations containing mixtures of soybean oil meal and the cottonseed meals were, in all cases, superior to the cottonseed meals when fed by themselves.

The antibiotic treatment (table 4) had no consistent effect on feed conversion. The pigs getting the combination of antibiotics were slightly less efficient than those fed penicillin only, but the difference was not statistically significant. Daily feed consumption was increased with all rations by adding the combination of antibiotics as compared to penicillin.

Summary

Using 72 weanling pigs fed in drylot, an experiment has been conducted to study the feeding value of two low gossypol cottonseed meals as compared to a good quality soybean oil meal. It was also possible to compare the growth stimulating value of procaine penicillin with a combination of procaine penicillin and erythromycin.

The results conclusively demonstrated that a degossypolized solvent extracted cottonseed meal (free gossypol content of 0.01% and nitrogen

solubility 89.0%) was superior to an expeller cottonseed meal (free gossypol content of 0.01%, and nitrogen solubility of 42.2%). When either of the cottonseed meals was partially replaced (25, 50 or 75%) with soybean oil meal the gains were significantly improved. In the case of the degossypolized solvent cottonseed meal it was observed that the combinations were equal or superior to soybean oil meal only.

The feeding of erythromycin in combination with procaine penicillin as an antibiotic fortification produced faster gains with all nine rations than did the feeding of procaine penicillin alone.

The results of this study indicate that low gossypol cottonseed meal can be used to good advantage as a protein supplement for weanling pigs, either as the sole source of supplementary protein or in combination with soybean oil meal. The most efficient rations in this study were those containing mixtures of the degossypolized solvent meal and soybean oil meal.

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EFFECTS OF ORALLY ADMINISTERED DIETHYLSTILBESTROL AND A FERMENTATION PRODUCT ON GROWING-FINISHING SWINE [1, 2]

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RECENT studies have amply demonstrated that increased gains and feed efficiency can be obtained by oral administration of stilbestrol to steers in dry-lot (Burroughs *et al.*, 1954 and others). Braude (1950) reported that barrows receiving iodinated casein and stilbestrol in the diet grew faster and utilized their feed more efficiently than animals on a control ration.

Using stilbestrol pellets implanted subcutaneously Dinusson *et al.* (1951), Woehling *et al.* (1951), and Pearson *et al.* (1952) found no consistent stimulation of growth in pigs. Perry *et al.* (1954) indicated no significant improvement in growth rate or feed efficiency when stilbestrol was fed in the protein supplement to growing-fattening pigs. The feeding of stilbestrol in combination with an antibiotic produced no faster growth than the antibiotic alone. Taylor *et al.* (1955) observed no significant effect on rate of gain or feed efficiency when stilbestrol was fed at several different levels in the diet of growing pigs.

The trials reported here were conducted to study the effects of stilbestrol on pig performance when fed at three levels with and without antibiotic supplementation. The supplementary value of a fermentation product was also studied.

Experimental Procedure

A total of 138 pigs, consisting of 70 gilts and 68 barrows, were used in three experiments. All pigs were fed in concrete dry-lot with feed and water provided *ad libitum*. Weights of the pigs were recorded at two-week intervals and feed consumption records maintained.

The composition of the basal ration used in the three experiments is presented in table 1.

[1] The authors wish to express appreciation to the following concerns for supplying materials used in these experiments: Eli Lilly and Co. for the diethylestilbestrol; American Cyanamid Co. for the Fortafeed 2–49c, Profactor–10, and Aurofac–10; and Dawes Laboratories, Inc. for the Fermentation Solubles, and vitamin A and D_2 supplements used.

[2] Acknowledgement is also due J. L. Carmon for assistance in the statistical evaluation of the results and to J. R. Danion for aid in caring for the animals.

[3] Contribution from the Department of Animal Husbandry, University of Georgia, Athens, Georgia. Journal Paper No. 25 of the College Experiment Station.

The basal mixture in each lot contained approximately 16% protein initially. This level was reduced to 14% as the pigs within each lot reached a weight of approximately 125 lb. The adjustment was made by varying the ratio of corn to soybean oil meal, other ingredients remaining constant.

Diethylstilbestrol was incorporated in the feed mixtures containing this ingredient by dissolving the crystalline material in cottonseed oil

TABLE 1. COMPOSITION OF RATION

Ingredients	Pounds
Ground yellow corn	71.8
Soybean oil meal	21.0
Dehydrated alfalfa meal	5.0
Limestone	1.0
Defluorinated phosphate	0.5
Salt	0.5
B-vitamin supplement [a]	0.1
Vitamin B_{12} supplement [b]	0.1
Vitamins A and D [c]	+

[a] Calculated to provide the following quantities per lb. of feed: riboflavin, 2 mg.; pantothenic acid, 4 mg.; niacin, 9 mg.; choline, 10 mg.; and folic acid, 60 mcg. Vitamin source was feed supplement Fortafeed 2–49c (Lederle).

[b] Calculated to provide 10 mcg. vitamin B_{12} per lb. of feed. Vitamin B_{12} provided by Profactor–10 (Lederle).

[c] Provided calculated quantities of 500 I.U. vitamin A and 100 I.U. of vitamin D_2 per lb. from Fixtay 5000 and Dry D_2 (Dawe's).

and mixing this solution with a portion of the solvent soybean oil meal. This pre-mixture was then blended with the remainder of the ration. An effective dispersion of the material was obtained in this way.

Chlortetracycline [4] was fed at a level of 18 gm. per ton of finished feed in those diets receiving the antibiotic.

Experiment I

Thirty-six Duroc and Duroc×Poland China pigs weighing approximately 36 lb. were employed in this trial. The pigs were assigned to six groups of six pigs each on the basis of weight, litter and sex. Each group of six pigs was then allotted at random to each of the six treatments as follows: Lot 1—Basal; Lot 2—Basal+antibiotic; Lot 3—Basal+0.5 mg. stilbestrol per lb. of feed; Lot 4—Basal+0.5 mg. stilbestrol+antibiotic; Lot 5—Basal+2.5 mg. stilbestrol per lb. of feed; Lot 6—Basal+2.5 mg. stilbestrol+antibiotic. Duration of the trial was 97 days.

[4] Provided by Aurofac–10 feed supplement (Lederle).

Experiment II

Forty-two Duroc pigs weighing approximately 43 lb. were divided into six comparable groups on the basis of weight, sex, litter and general thriftiness. These groups of seven pigs each were then randomized to the following treatments: Lot 1—Basal; Lot 2—Basal+antibiotic; Lot 3—Basal+0.5 mg. stilbestrol per lb. of feed; Lot 4—Basal+0.5 mg. stilbestrol per lb.+antibiotic; Lot 5—Basal+2.0 mg. stilbestrol per lb., Lot 6—Basal+2.0 mg. stilbestrol per lb.+antibiotic.

TABLE 2. AVERAGE PERFORMANCE DATA FOR EXPERIMENT I

Lot No.	1	2	3	4	5	6
Treatment	Basal	Basal +antibiotic	Basal +0.5 mg. stil./lb.	Same as 3 +antibiotic	Basal +2.5 mg. stil./lb.	Same as 5 +antibiotic
Number of pigs	6	6	6	6	6	6
Av. initial weight, lb.	35.7	35.7	36.2	35.5	35.5	36.2
Av. final weight, lb.	162.7	175.0	143.2	152.5	169.0	199.6
Av. daily gain, lb.	1.32	1.45	1.11	1.22	1.39	1.67*
Av. daily feed consumption, lb.	5.40	5.52	4.51	4.45	5.01	5.45
Av. feed required per 100 lb. gain	408	381	405	365	362	321

* Difference significant at 5% level.

Lots 5 and 6 were started on diets containing 2.5 mg. of stilbestrol per lb., but this was reduced to 2.0 mg. after the experiment had been in progress for six days because of vaginal prolapse developing with one pig in each of these groups. Duration of the trial was 96 days.

Experiment III

Ten litters of six Duroc pigs each were randomized to six groups and these groups were allotted at random to the following six treatments: Lot 1—Basal; Lot 2—Basal+antibiotic; Lot 3—Basal+3% fermentation solubles; Lot 4—Basal+6% fermentation solubles; Lot 5—Basal+2.0 mg. stilbestrol per lb.; Lot 6—Basal+2.0 mg. stilbestrol +antibiotic. The fermentation solubles were added at the levels indicated to each 100 lb. of basal mixture. Duration of the trial was 86 days.

Results and Discussion

Average performance data for the three experiments are presented in tables 2, 3 and 4. Covariance analysis was used to adjust for differences in initial weight of the pigs in all expreiments.

TABLE 3. AVERAGE PERFORMANCE DATA FOR EXPERIMENT II

Lot No.	1	2	3	4	5	6
Treatment	Basal	Basal +antibiotic	Basal +0.5 mg. stil./lb.	Same as 3 +antibiotic	Basal +2.0 mg. stil./lb.	Same as 5 +antibiotic
Number of pigs	7	7	7	7	5[1]	6[2]
Av. initial weight, lb.	43.1	42.4	42.9	42.3	45.2	46.1
Av. final weight, lb.	193.7	194.6	182.1	201.3	207.8	210.2
Av. daily gain, lb.	1.57	1.58	1.45	1.66	1.69	1.72
Av. daily feed consumption, lb.	6.04	6.16	5.75	6.36	6.76	6.01
Av. feed required per 100 lb. gain, lb.	384	389	397	384	398	352

[1] One pig removed with vaginal prolapse early in the experiment. Another pig was removed as a result of a rectal prolapse.
[2] One pig removed with vaginal prolapse early in the experiment.

Analysis of the growth data from Experiment I indicated a significant interaction between the antibiotic and stilbestrol as fed in Lots 4 and 6. While the addition of the antibiotic in Lots 2 and 4 appeared to stimulate rate of gain, these differences were not significant when tested statistically. Neither did the addition of stilbestrol at two levels to the basal ration (Lots 3 and 5) produce a significant response. The addition of stilbestrol at the low level (Lots 3 and 4) appeared to depress growth slightly as compared to Lots 1 and 2 and those receiving the higher level of stilbestrol (Lots 5 and 6).

Swelling of the vulva was observed among the gilts receiving both levels of stilbestrol on the second and third days after being placed on feed. Teat enlargement was apparent among both barrows and gilts in all lots receiving stilbestrol.

One gilt was removed from each of Lots 5 and 6 of Experiment II with a prolapse of the vagina. As explained previously, these two lots were originally started on stilbestrol levels of 2.5 mg. per lb. of feed.

TABLE 4. AVERAGE PERFORMANCE DATA FOR EXPERIMENT III

Lot No.	1	2	3	4	5	6
Treatment	Basal	Basal +antibiotic	Basal+3% ferm. sols.	Basal+6% ferm. sols.	Basal +2.0 mg. stil./lb.	Same as 5 +antibiotic
Number of pigs	10	10	10	10	10	10
Av. initial weight, lb.	44.0	44.2	44.3	44.7	42.4	42.4
Av. final weight, lb.	187.9	196.7	189.7	176.8	181.7	191.8
Av. daily gain, lb.	1.67	1.77*	1.69	1.54	1.62	1.74*
Av. daily feed consumption, lb.	5.58	6.16	5.88	5.22	5.53	5.58
Av. feed required per 100 lb. gain, lb.	333	346	349	340	342	322

* Difference significant at 5% level.

This level had been used in Experiment I with no difficulty of this nature. However, feed consumption in Experiment I was less, presumably because of the hot weather prevailing during most of the trial. This would have resulted in a smaller daily dosage of stilbestrol than was the case in Experiment II which was conducted during the winter months. After reducing the stilbestrol level in the diet of these lots to 2.0 mg. per lb. of feed, no further trouble was experienced. One barrow was removed from Lot 5 later in the trial with a rectal prolapse which apparently was not associated with the treatment.

Although a greater growth response was obtained in Lots 4, 5 and 6 in Experiment II than in the control group (Lot 1), these differences were not significant when statistical treatment was applied. There was no significant interaction between stilbestrol and the antibiotic in Experiment II, although there was a slight difference in that direction. The low level of stilbestrol appeared to have a slight depressing effect on growth which is consistent with the results of Experiment I.

After adjusting for initial weights and removing litter variation in Experiment III, a significant increase in average daily gain was found in Lots 2 and 6 which received the antibiotic. The addition of stilbestrol to the ration was without effect on rate of gain either alone (Lot 5) or in combination with the antibiotic (Lot 6). The addition of 3% fermentation solubles to the basal ration produced no supplementary effect. The addition of 6% fermentation solubles resulted in a significant decrease in average daily gain. This decrease was apparently due to reduced palatability of this mixture, since feed consumption in this lot (Lot 4) was somewhat less than in the other lots.

There was considerable variation in efficiency of feed utilization between the three trials. However, feed utilization appeared to be consistently improved in the lots receiving the combination of high level stilbestrol and antibiotic in all instances. Daily feed consumption appeared to be less with pigs receiving the low level of stilbestrol (Lot 3) in both Experiment I and II, which apparently explains the slower rate of gain obtained in those lots. The reason for this reduction in daily feed intake is not readily apparent.

Summary

Three experiments have been conducted to study the effects of orally administered stilbestrol on growing swine when fed at two dietary levels with and without antibiotic supplementation. A fermentation product was also studied.

Although statistical treatment indicated a significant interaction was obtained from the combination of high level stilbestrol and the antibiotic in Experiment I, this effect was not confirmed by the results of Experiments II and III. The feeding of stilbestrol in combination with an antibiotic in Experiments II and III resulted in no greater growth response than was obtained with the antibiotic alone. Antibiotic supplementation produced a consistent growth response.

Feeding stilbestrol at the levels employed in these experiments apparently had no consistent growth stimulating effect. A trend toward more efficient feed utilization was noted in those lots receiving the combination of high level stilbestrol and antibiotic in all instances.

The addition of 3% fermentation solubles to the basal ration produced no supplementary effect; however, the addition of 6% fermentation solubles resulted in a significant decrease in average daily gain.

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THE ISOLEUCINE REQUIREMENT OF WEANLING SWINE FED TWO PROTEIN LEVELS

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STUDIES at the Illinois Station by Becker *et al.* (1954, 1955a, 1955b) on the lysine, tryptophan, and methionine-cystine requirements of the weanling pig indicated lower needs than theretofore reported. That these amino acid requirements were lower may have been due to the fact that less protein was used in our experiments than that used in earlier experiments.

Evidence obtained with the chick indicates that the protein level fed can influence amino acid needs. Almquist (1952) reviewed studies showing that the dietary need of the chick for lysine, arginine, and sulfur-bearing amino acids varies directly with the protein level of the diet. However in the cases of lysine and methionine-cystine, Grau and Kamei (1950) noted that the variation in dietary amino acid need is not a fixed percentage of the dietary protein. With the pig, Brinegar *et al.* (1950) reported that the lysine needs on diets containing 10.6 and 22% protein were 5.7 and 5.5% of the protein, respectively.

The lone direct study of the isoleucine need of swine was conducted by Brinegar *et al.* (1950) using a diet containing approximately 22% protein. At this level of protein, the maximum growth and feed efficiency were obtained with a diet containing 0.7% L-isoleucine, which is equivalent to 3.2% of the dietary protein.

The objective of the studies reported here was to determine the isoleucine requirement of young swine when fed at two levels of dietary protein.

Experimental

Three experiments were conducted with pigs weighing approximately 30 lb. initially and which had been fed adequate diets prior to the start of the test. A description of the diets used is presented in table 1, and it is particularly noteworthy that the two-fold level of blood

[1] The authors wish to acknowledge Dow Chemical Co., Midland, Michigan; Merck & Co., Rahway, New Jersey; Commercial Solvents Corporation, Terre Haute, Indiana; Chas. Pfizer & Co., Inc., Brooklyn, New York; and American Cyanamid Company, Pearl River, New York; for funds and products which made this investigation possible.

TABLE 1. PERCENTAGE COMPOSITION OF DIETS FED

Diet designation	A	B
Ingredients:		
Corn starch	64.4	49.3
Soluble blood flour [a]	15.0	30.0
Dextrose	10.0	10.0
Woodflock	3.0	3.0
Crude corn oil	3.0	3.0
Mineral mixture #2 [b]	4.0	4.0
Vitamin A and D oil (3000A–600D)	0.5	0.5
DL-methionine	0.1	0.2
Vitamin mixture #26 [c]	+	+
Chlortetracyclie HCl (25 mg. per lb.)	+	+
Composition:		
Crude protein (N×6.25) [d]	13.35	26.70
Arginine	0.63	1.26
Histidine	0.52	1.04
Isoleucine [d]	0.20	0.39
Leucine	2.11	4.22
Lysine	1.20	2.40
Methionine (L+DL) [d]	0.25	0.50
Cystine [d]	0.28	0.56
Threonine	0.99	1.98
Tryptophan	0.22	0.44
Valina	0.82	1.64
Phenylalanine	0.93	1.86
Tyrosine	0.57	1.14
Ether extract [d]	3.65	3.76
Gross energy (kcal. per gm.) [d]	3818.	4039.

[a] Manufactured by Wilson & Co., Chicago 9, Illinois.
[b] Becker & Terrill (1954).
[c] Becker, Ullrey and Terrill (1954).
[d] Values determined by actual analysis. Amino acid values determined by assay according to the method of Henderson and Snell (1948) in the laboratory of Wisconsin Alumni Research Foundation.

flour and DL-methionine in diet B maintains the identical ratio of amino acids to each other in the two diets.

Thirty-six Duroc pigs formed into six outcome groups equalized on the basis of ancestry, weight, and general condition were used in Experiment 1. The pigs were allotted to the isoleucine levels at random from the outcome groups, and pairs of outcome groups were allotted at random to the two diets or protein levels studied. The pigs were kept in concrete pens and the diets were hand-fed in individual feeding crates two times daily. Feeding level was at a full-intake basis. The isoleucine treatments are described in the table of results. The feeding period was for 30 days.

Twenty Duroc and a combination of 20 Duroc or crossbred pigs were used in Experiments 2 and 3, respectively. In each case, the pigs were allotted to the isoleucine levels at random from outcome groups or four pigs each equalized for ancestry, weight, and general condition. The isoleucine treatments are described in the table of results. The feeding and management practices were the same as in the previous test, except

TABLE 2. RESPONSE OF THE GROWING PIG TO LEVELS OF ISOLEUCINE IN DIETS CONTAINING TWO PROTEIN LEVELS
(Experiment 1)

Level of L-isoleucine added, %		0.13	0.26	0.39	0.52	0.65	Av.
Level of L-isoleucine fed, %							
Diet A	0.20	0.33	0.46	0.59	0.72	0.85	
Diet B	0.39	0.52	0.65	0.78	0.91	1.04	
Av. initial wt., lb.							
Diet A	31.7	31.3	31.0	34.3	31.0	34.3	32.3
Diet B	30.7	33.0	33.0	30.3	30.7	30.0	31.3
Av.	31.2	32.2	32.0	32.3	30.8	32.2	31.8
Av. daily gain, lb.							
Diet A	0.06	0.77	0.93	1.06	0.94	1.04	0.80
Diet B	0.12	0.82	1.07	1.01	1.17	1.02	0.87
Av.	0.09	0.79	1.00	1.03	1.06	1.03	0.84
Av. daily feed intake, lb.							
Diet A	0.86	1.94	2.07	2.28	1.98	2.14	1.88
Diet B	1.00	1.81	1.95	1.85	2.10	1.80	1.75
Av.	0.93	1.87	2.01	2.06	2.04	1.97	1.82
Gain per lb. feed, lb.							
Diet A	0.06	0.40	0.45	0.46	0.48	0.49	0.43
Diet B	0.12	0.45	0.55	0.55	0.56	0.57	0.50
Av.	0.10	0.42	0.50	0.50	0.52	0.52	0.46

the equal feeding technique as described by Mitchell and Beadles (1930) was used. The feeding period was 28 and 27 days in Experiments 2 and 3, respectively.

In all tests supplementary L-isoleucine was added as a 32% concentrate, the remainder of which was made up of D-alloisoleucine.

The data were treated statistically by analysis of variance as outlined by Snedecor (1946).

Results

The levels of isoleucine, feed data, and gain data of Experiment 1 are presented in table 2.

The performance of the pigs fed the unsupplemented control diets

was practically the same. With both diets the pigs exhibited marked anorexia, arrested or depressed growth, and inefficient utilization of feed. In addition, the pigs exhibited unkempt hair coats, unthriftiness, lack of fleshing, and the usual non-specific symptoms typical of a deficiency of protein or amino acids or both. In other words, the control diets appeared to be equally deficient, in spite of the two-fold isoleucine content of diet B.

The control diets were markedly improved by the addition of 0.13% L-isoleucine, and maximum performance was noted when 0.26% L-isoleucine was added to the diets. Efficiency of feed utilization, expressed

TABLE 3. ANALYSES OF VARIANCE OF MEAN DAILY GAIN, DAILY FEED INTAKE, AND GAIN PER POUND OF FEED IN EXPERIMENT 1

		Mean square		
Source of variance	d/f	Daily gain	Feed intake [a]	Gain per lb. of feed
Protein level (P)	1	0.0427	0.1419	0.0514
Pair groups (G)	2	0.0290	0.1299	0.0198
P×G	2	0.0116	0.0087	0.0131
Isoleucine levels (I)	5	0.8504**	1.1607**	0.1886**
P×I	5	0.0143	0.0812*	0.0004
G×I	10	0.0355*	0.0922**	0.0084*
P×G×I	10	0.0100	0.0146	0.0022

[a] Isoleucine levels tested by the approximate F-test given by Cochran (1951).
* Significant at 5% level.
** Significant at 1% level.

as gain per pound of feed consumed, exhibited a similar response to the supplementary isoleucine levels. Hence, with diet A, which contained 13.35% protein, 0.46% isoleucine supported rate and efficiency of gain equal to that of higher levels. However, diet B, which contained twice the level of protein of diet A, required 0.65% isoleucine to support satisfactory performance.

Analyses of variance of mean daily gains, daily feed intake, and feed efficiency are presented in table 3. For mean daily gains the isoleucine levels yielded differences which were significant statistically (P=0.01). However, the pair groups reacted differently to the isoleucine levels, the heavier pair groups growing faster, consuming more feed, and gaining more efficiently on the lower isolucine levels than the lighter pair groups. In addition, there was a significant (P=0.05) interaction of protein levels and isoleucine levels in daily feed intake.

There was some evidence that diet A may have been slightly deficient

in protein or amino acids or both for the light-weight pigs. The lighter pair groups made less gain per pound of feed consumed on the low-protein than on the high-protein diet; whereas, there was no difference between protein levels with the heavier-pair groups.

Levels of isoleucine, feed data, and gain data of Experiments 2 and 3 are presented in table 4.

In general, the response to the levels of isoleucine in the latter trials

TABLE 4. RESPONSE OF THE GROWING PIG TO LEVELS OF ISOLEUCINE IN DIETS CONTAINING TWO PROTEIN LEVELS (EXPERIMENTS 2 AND 3)

Level of L-isoleucine added, %	0.13	0.26	0.39	0.52
Experiment 2—13.35% protein (Diet A)				
Level of L-isoleucine, %	0.33	0.46	0.59	0.72
No. of pigs	5	5	5	5
Av. initial wt., lb.	36.6	34.0	35.2	36.6
Av. daily gain, lb.	0.93	1.13	1.14	1.13
Av. daily feed intake, lb.	2.07	2.07	2.07	2.07
Gain per lb. feed, lb.	0.45	0.54	0.55	0.54
Experiment 3—26.70% protein (Diet B)				
Level of L-isoleucine, %	0.52	0.65	0.78	0.91
No. of pigs	5	5	5	5
Av. initial wt., lb.	30.5	29.4	29.8	27.6
Av. daily gain, lb.	0.25[a]	0.79	0.83	0.84
Av. daily feed intake, lb.	0.98	1.40	1.40	1.40
Gain per lb. feed, lb.	0.26	0.56	0.59	0.60

[a] Since pigs fed 0.52% L-isoleucine exhibited a low and erratic feed intake, they were fed on an *ad libitum* basis.

parallels the findings of Experiment 1. In Experiment 2, with the 13.35%-protein diet it was noted that 0.33% L-isoleucine was inadequate to support maximum growth and feed efficiency, and 0.46% was equal to the higher levels. The analysis of variance of the mean daily gains showed a statistically significant ($P=0.01$) effect of the isoleucine levels. In Experiment 3, 0.52% isoleucine was insufficient for satisfactory feed intake, weight gains, or feed efficiency in the high-protein diet. Performance was considerably poorer at the lowest isoluecine level in Experiment 3 than previously observed with the same diet in Experiment 1. In fact, performance was so poor on the lowest isoleucine level that it was considered advisable to equate feed intake of the remaining groups on the basis of the intake of the pigs feed 0.65% isoleucine. There was no statistically significant influence of the three highest levels of isoleucine on the mean daily gains. A summary of the analysis

of variance of the mean daily gains in Experiment 2 and 3 is presented in table 5.

In comparing the last two trials, it may be noted that the gain per pound of feed consumed was practically the same. However, rate of gain was less in Experiment 3, probably a reflection of the feeding technique and the thriftiness of the pigs employed.

Discussion

It has been adequately demonstrated by Rose (1938) and by Albanese (1945) that the rat cannot utilize D-isoleucine for growth. Moreover, Rose (1938) reported that both D- and L-alloisoleucine are completely

TABLE 5. ANALYSIS OF VARIANCE OF MEAN DAILY GAIN IN EXPERIMENTS 2 AND 3 [a]

	Experiment 2		Experiment 3 [a]	
	d/f	Mean square	d/f	Mean square
Isoleucine levels (I)	3	0.0491**	2	0.0030
Outcome groups (G)	4	0.1162**	4	0.0182**
I×G	12	0.0025	8	0.0016

[a] Statistical analysis does not include the pigs on the lowest level of L-isoleucine, since they were fed *ad libitum* rather than on an equal feeding basis.
* Significant at 1% level.

incapable of replacing the natural form of isoleucine for rat growth. Greenstein *et al.* (1951) have verified the latter finding of Rose. Hence, in the studies reported here it has been assumed that the diastereoisomer of isoleucine, as well as other unnatural isomers which may be contaminants, are completely unavailable to support growth in the pig.

At 13.35 and 26.70% dietary protein the isoleucine need was found to be 0.46 and 0.65% of the diet or 3.4 and 2.4% of the dietary protein, respectively. Assuming a linear relationship between dietary protein and isoleucine requirement, expressed as a percentage of the protein, the isoleucine requirement within the dietary protein range studied may be expressed by the equation, $\hat{Y}=4.5-0.07\ X$, where $\hat{Y}$ is the isoleucine need and X is the percentage of dietary protein.

Previously, Brinegar *et al.* (1950) concluded that weanling pigs fed a diet similar to that employed here, except that it contained 22% protein, required 0.7% L-isoleucine in the diet. This amino acid requirement is equivalent to 3.2% of the dietary protein, and with 13.35 and 26.70% dietary protein the calculated isoleucine need would be 0.43 and 0.85% of the diet, respectively. Thus, the estimated amino

acid need at the higher level of dietary protein is excessive. On the other hand, according to the equation presented above the isoleucine need at 22% dietary protein should be 2.78% of the protein or 0.61% of the diet. The data published by Brinegar *et al.* indicate that the isoleucine need of the pig fed 22% protein lies between 0.58 and 0.70% of the diet, and our data are compatible with this observation.

It is interesting to compare the requirement figures as found in this study with the estimate of Williams *et al.* (1954) using the tissue analysis technique. They calculated that the requirement for isoleucine is 0.50% of the diet when lysine is used as the standard at 1.10% of the diet. However, when a more realistic figure for lysine required is used as the standard, for instance, the estimated figures of 0.72% of a 12.0% protein diet published by Becker *et al.* (1954), then the isoleucine need on the basis of tissue distribution can be calculated at 0.32% of the diet. The calculated values do not agree well with the responses noted here. There may be at least two reasons for this variation. Since the level of dietary protein appears to exert a significant effect, it is noteworthy that calculated amino acid needs on the basis of tissue distribution yields little information on this point. In addition, some differences may arise since the tissue assay technique estimates only physiological needs for tissue growth rather than dietary requirements to satisfy the total demand.

Of course, the requirements established in this study apply to dietary regimens of similar caloric density. Any decrease in the caloric density which would increase the quantity of feed ingested to satisfy caloric requirements would concurrently decrease the percentage of protein or amino acids or both required in the diet. The diets employed in these studies were high in digestible energy, since they were calculated to contain 88% total digestible nutrients. Using the formula of Maynard (1953) for converting total digestible nutrients to digestible energy, it was estimated that the high- and low-protein diets contained 1770 and 1690 kcal. of digestible energy per pound, respectively. Hence, with the low protein diet the isoleucine need may be expressed as 0.52% of the total digestible nutrients or 0.27 pound per 1000 kcal. of digestible energy. On the other hand, with the high protein diet the isoleucine need was 0.74% of the total digestible nutrients or 0.37 lb. per 1000 kcal. of digestible energy.

In studies of this nature the query of practical import of the nutrient usually arises, although, heretofore, isoleucine has not been granted much attention by the practical feeder. Usually weanling pigs are fed

diets containing 16% protein and 75% total digestible nutrients, and with such a diet the pig would require 0.45% isoleucine. Using average figures, it has been calculated that a yellow corn-soybean oil meal diet would contain 0.83% isoleucine and a yellow corn-blood flour diet would contain 0.47% isoleucine. Hence, in dietary regimens in which yellow corn contributes approximately 50% of the total protein an isoleucine deficiency appears unlikely.

Summary

Three experiments were conducted with weanling pigs to measure the isoleucine requirement and its relation to the dietary protein level. A synthetic diet containing soluble blood flour supplemented with methionine was used as an isoleucine-deficient diet and was calculated to contain 88% total digestible nutrients. Supplementary L-isoleucine was added as a 32% concentrate with D-alloisoleucine as the remainder.

With a diet containing 13.35% protein the maximum rate and efficiency of gain were obtained with a minimum level of 0.46% L-isoleucine, equal to 3.4% of the dietary protein. On the other hand, with 26.70% protein the maximum rate and efficiency of gain occurred at a minimum level of 0.65% L-isoleucine, equal to 2.4% of the dietary protein. The L-isoleucine need in the high- and low-protein diets was 0.74 and 0.52% of the total digestible nutrients, respectively.

Assuming a linear relationship between dietary protein and isoleucine requirement, expressed as a percentage of the protein, the isoleucine need within the protein range studied may be expressed by the equation, $\hat{Y}=4.5—0.076X$, where $\hat{Y}$ is the isoleucine need and X is the percentage of dietary protein.

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THE INFLUENCE OF CHLORTETRACYCLINE ON THE REQUIREMENT OF THE YOUNG PIG FOR DIETARY PANTOTHENIC ACID [1]

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HUGHES (1942), Wintrobe *et al.* (1942) and Ellis *et al.* (1943) established that inadequate levels of pantothenic acid in swine rations resulted in sub-normal appetites, slow growth, emaciation, hair-loss, diarrhea, involvement of the large intestine and muscular incoordination. These investigators, as well as Luecke *et al.* (1949, 1950, 1953) and Wiese (1951) prevented the appearance of these symptoms by the addition of calcium pantothenate to rations containing suboptimal levels of this vitamin, but nutritionally adequate in other respects.

Lih and Baumann (1951), Sauberlich (1952), Daft and Schwarz (1952), Guggenheim *et al.* (1953), Schendel and Johnson (1954) and Jones and Baumann (1955) have reported that chlortetracycline stimulated growth and prevented the appearance of deficiency symptoms in rats receiving diets devoid of or lacking in pantothenic acid.

Catron *et al.* (1953) concluded that chlortetracycline (10 mg. per lb.) had a sparing effect on the pantothenic acid requirements of growing-fattening swine receiving corn-soybean oil meal rations. However, animals receiving pantothenic acid-low rations in their experiments failed to demonstrate pantothenic acid deficiency symptoms. Luecke *et al.* (1953) observed pantothenic acid deficiency symptoms in pigs receiving a ration similar to those used by Catron *et al.*, and found that the addition of chlortetracycline (5 mg. per lb.) to this ration had no sparing action for pantothenic acid.

The object of the study reported herein was to determine the effect of supplementing a low-protein corn-soybean oil meal ration with chlortetracycline on the pantothenic acid requirements of early weaned pigs in drylot, using growth performance and tissue analyses as criteria.

Experimental

In each of two trials, 27 five-week old weanling Duroc pigs were allotted into three dietary groups, consisting of nine trios formed accord-

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ing to weight, sex and litter. Each pig was maintained in an individual concrete pen. The pigs in group 1 received a basal ration consisting of the following ingredients (in percent): ground yellow corn 82.0; solvent soybean oil meal, 16.0; ground limestone, 1.0; steamed bone meal, 0.5; and salt-trace mineral mix, 0.53. The following vitamins were added per pound of basal ration: vitamin A, 2000 I.U.; vitamin D_2, 400 I.U.; choline chloride, 400 mg.; niacin, 10 mg.; riboflavin, 2.3 mg.; pyridoxine, 1.2 mg.; folic acid, 0.5 mg.; and vitamin B_{12}, 14 mcg. For the two trials, crude protein content was: 14.40 and 14.66%, respectively. Assays of the rations for pantothenic acid showed the content to be: 3.08 and 3.04 mg. per pound, respectively for trials 1 and 2.

The pigs in group 2 received the basal ration supplemented with 6.2 mg. of pantothenic acid per pound. Group 3 pigs received the basal ration supplemented with 10 mg. of chlortetracycline per pound.

All pigs were fed and watered ad libitum. The live weights and feed consumption were determined weekly. One-third of the animals in each group were removed from experiment and sacrificed at the end of six weeks, one-third after nine weeks, and the remaining animals after twelve weeks.

The concentration of pantothenic acid in the brain cerebrum, heart left ventricle, kidney cortex and right central lobe of the liver of all animals was determined. The method of Ives and Strong (1946) was followed in preparation of the rations and tissue samples for pantothenic acid assay.

Results and Discussion

The growth rate, feed consumption and feeding efficiency data are summarized in table 1. A summary of the analysis of variance for these criteria is presented in table 2. Supplementation of the basal ration with chlortetracycline significantly increased average daily gains and daily feed consumption ($P=.01$). Although pantothenic acid supplementation did not increase these factors significantly, efficiency of feed utilization was increased significantly ($P=.05$). Likewise, chlortetracycline supplementation increased feeding efficiency significantly ($P=.01$). While there was a more rapid rate of growth in the first trial, relative performance of the three experimental groups within the two trials was quite similar.

During the 4th and 5th weeks of both trials, eight of the nine pigs receiving the basal ration developed a severe diarrhea, which persisted until the time of sacrifice. This condition was found to be accompanied

TABLE 1. SUMMARY OF GROWTH AND FEED DATA FOR TRIAL 1 (SUMMER–1955) AND TRIAL 2 (WINTER–1955)

Ration treatment	Trial 1				Trial 2				
	Time on experiment				Time on experiment				
	6 wk.	9 wk.	12 wk.	Av.	6 wk.	9 wk.	12 wk.	Av.	Grand av.
	Average daily gains, lb.[a]								
Basal	.95	1.08	1.42	1.15	.78	1.09	1.11	.99	1.07
Basal & P.A.	1.11	1.24	1.41	1.25	.90	1.00	1.12	1.01	1.13
Basal & chlortetracycline	1.22	1.30	1.54	1.35	.91	1.14	1.20	1.11	1.24
	Daily feed consumption, lb.								
Basal	2.64	2.52	4.06	3.07	2.12	3.08	3.32	2.84	2.96
Basal & P.A.	2.99	3.09	3.81	3.30	2.38	2.62	3.36	2.79	3.04
Basal & chlortetracycline	3.24	3.17	4.34	3.58	2.27	3.07	3.56	2.97	3.33
	Feed consumed per pound gain, lb.								
Basal	2.48	2.48	2.90	2.62	2.72	2.82	3.00	2.85	2.73
Basal & P.A.	2.42	2.61	2.73	2.58	2.65	2.61	3.02	2.76	2.68
Basal & chlortetracycline	2.38	2.57	2.86	2.60	2.51	2.67	2.96	2.74	2.67

[a] Average initial weight of trial 1, 20 lb.; of trial 2, 16 lb.

TABLE 2. SUMMARY OF ANALYSIS OF VARIANCE OF AVERAGE DAILY GAINS, AVERAGE DAILY FEED CONSUMPTION AND FEED REQUIRED PER POUND OF GAIN

Source of variation	d.f.	Av. Daily gain	Daily feed consumption	Feed per lb. gain
		Mean square	Mean square	Mean square
Trials	1	0.6430**	2.4586**	0.4172**
Rations	2	0.1233**	0.6797**	0.0241**
Age at sacrifice	2	0.4415**	5.9208**	0.6917**
Trial×ration	2	0.0020	0.0778	0.0078
Trial×age	2	0.0072	0.7941	0.1703
Ration×age	4	0.0021	0.0126	0.0142
Trial×ration×age	4	0.0408*	0.6445**	0.0384**
Pigs within subgroups	35	0.0153	0.0954	0.0045

* Significant at 5% level.
** Significant at 1% level.

by inflammation of the large intestine in numerous animals (table 3). Lameness of the rear legs was observed in only one pig in the first trial, while seven animals in the second trial were definitely lame. This condition approached a true goose-step in three animals. Histological studies revealed pathological changes in the nervous system similar to those reported by Wintrobe *et al.* (1940, 1942), Ellis and Madsen (1941), Luecke *et al.* (1951) and Stothers *et al.* (1955), in five of the seven pigs. In the second trial, blood was observed in the feces of five of the nine animals and coprophagy was noticed in the three pigs left on experiment for 12 weeks. The data in table 3 further demonstrate that pigs receiving the basal ration in the second trial were more adversely affected than those in the first trial. Pantothenic acid deficiency

TABLE 3. INCIDENCE OF PANTOTHENIC ACID DEFICIENCY SYMPTOMS OBSERVED IN PIGS RECEIVING BASAL RATION IN TRIALS 1 AND 2

Time of sacrifice	Diarrhea	Blood in feces	Inflammation of large intestine	Lameness	Coprophagy
			Trial 1		
wk.					
6	3	0	2	0	0
9	2	0	1	1	0
12	3	0	0	0	0
			Trial 2		
6	3	2	3	1	0
9	3	1	1	3	0
12	2	2	1	3	3

TABLE 4. CONCENTRATION OF PANTOTHENIC ACID IN ORGANS OF PIGS IN TRIAL 1 AND TRIAL 2 *

Ration treatment	Trial 1				Trial 2				
	Time on experiment				Time on experiment				
	6 wk.	9 wk.	12 wk.	Av.	6 wk.	9 wk.	12 wk.	Av.	Grand av.
				Brain cerebrum					
Basal	22.3	18.1	20.8	20.4	11.3	14.3	12.4	12.7	16.5
Basal & P.A.	30.2	28.8	20.6	26.5	7.3	8.1	7.7	7.7	17.1
Basal & chlortetracycline	21.3	22.0	13.3	18.9	11.7	9.0	9.3	9.8	14.6
				Heart left ventricle					
Basal	4.4	7.7	13.8	8.6	9.4	9.3	10.5	9.7	9.2
Basal & P.A.	13.8	13.8	6.6	11.4	9.9	13.0	12.3	11.8	11.6
Basal & chlortetracycline	4.1	14.3	11.0	9.8	10.9	8.4	8.8	9.1	9.5
				Kidney cortex					
Basal	39.5	22.4	25.2	29.1	18.0	18.1	14.4	16.8	23.0
Basal & P.A.	31.3	33.9	15.1	26.8	11.2	13.9	11.7	12.3	19.5
Basal & chlortetracycline	21.7	26.1	15.0	20.9	10.3	6.6	8.6	8.3	15.0
				Liver right central lobe					
Basal	14.9	38.4	38.4	30.5	26.3	22.2	18.7	22.4	28.0
Basal & P.A.	25.2	45.1	53.7	41.3	23.3	20.8	16.7	20.3	30.8
Basal & chlortetracycline	16.6	60.9	70.4	49.3	36.3	43.1	28.4	35.9	40.6

* Expressed as micrograms of pantothenic acid per gram fresh tissue.

symptoms were not observed in any of the pigs in groups 2 or 3 where pantothenic acid and chlortetracycline were added to the rations, respectively.

This difference in response may have been influenced by the following factors: (a) average initial weight (1st trial, 20 lb.; 2nd trial, 16 lb.); (b) the pigs in trial 1 had been on dirt (without access to forage) for three weeks prior to weaning, while those in trial 2 were never off concrete; (c) genetic differences; (d) season (summer, trial 1 vs. winter, trial 2); or, (e) combinations of these factors or even some other reason.

TABLE 5. SUMMARY OF ANALYSES OF VARIANCE OF PANTOTHENIC ACID CONCENTRATIONS IN VARIOUS ORGANS

		Brain	Heart	Kidney	Liver
Source of variation	d.f.	Mean square	Mean square	Mean square	Mean square
Trials	1	1868.5**	1.2838	2230.**	2605.**
Rations	2	29.9	30.2923**	279.*	1171.**
Age at sacrifice	2	62.2	28.9145**	269.*	1209.**
Trial×ration	2	142.8	34.3197	35.	218.
Trial ×age	2	35.9	19.5764	107.	2141.**
Ration×age	4	16.9	33.5697	55.	188.
Trial×ration×age	4	145.3**	94.5346**	93.	92.
Pigs within subgroups	35	25.4	3.7259	59.	138.

* Significant at 5% level.
** Significant at 1% level.

Table 4 summarizes the data obtained concerning the concentration of pantothenic acid in the various tissues assayed. A summary of analysis of variance of this data is shown in table 5.

The pigs of trial 1 had significantly higher (P=.01) levels of the vitamin in all of the tissues assayed except the heart ventricle. Hearts from the pigs in group 2 had significantly higher (P=.01) levels of pantothenic acid than those of groups 1 and 3. Hearts from animals sacrificed at 9 and 12 weeks had significantly higher (P=.01) levels than those sacrificed at 6 weeks.

The concentration of pantothenic acid in the brain cerebrum was not affected to a significant degree by either ration treatment or age at sacrifice. Pigs from group 3 had significantly lower (P=.05) kidney cortex levels of the vitamin than groups 1 and 2; pigs sacrificed at 12 weeks had significantly lower kidney values than those sacrificed at 6 weeks (P=.05) or 9 weeks (P=.06). Pigs in group 3 had significantly

higher concentration of pantothenic acid in the liver than group 1 ($P=.01$) or group 2 ($P=.05$). The animals sacrificed at 9 and 12 weeks had significantly higher ($P=.01$) liver values than those sacrificed at 6 weeks. Analysis of covariance showed no correlation between kidney and liver pantothenic acid concentration in individual animals.

Hegsted and Riggs (1949) found that the pantothenic acid concentration in the liver of chicks tended to increase with increased intake of the vitamin, but noted great variability. Their conclusion was that the liver concentration of pantothenic acid was not a sensitive criterion of a deficiency of the vitamin in chicks. This also appears to be the case in this study; however, liver concentration was a better criterion than the other tissues studied.

Guggenheim *et al.* (1953) reported that chlortetracycline supplementation of a diet low in pantothenic acid had a marked stimulation on the growth of rats, which was generally associated with increased urinary excretion and a greater liver level of this vitamin. Thus, it is possible that the lower kidney pantothenic acid values encountered in these pigs having high liver levels may be associated in some manner with increased urinary excretion of the vitamin.

Schendel and Johnson (1954) found that when chlortetracycline was included in diets containing no pantothenic acid, growth stimulation of rats was only 68% as effective when this vitamin was injected as when it was fed. Guggenheim *et al.* (1953) found that subcutaneous injections of the antibiotic had no effect on growth or the accumulation of pantothenic acid in the liver of rats on pantothenic acid-low diets. This would indicate that this apparent vitamin-sparing effect of chlortetracycline is due to some influence on the intestinal flora or possibly the intestine itself rather than because of any direct action on the vitamin economy of the body.

Of the tissues studied, the concentration of pantothenic acid in the liver was in closest agreement with the rate of growth, appetite and outward appearance of the animals as indicators of the adequacy of the nutritional state in regards to this vitamin. The variations encountered are probably reflections of the variability of individuals in utilization of the vitamin present in the ration and in metabolism and possibly ability to store the vitamin within the organism.

It appears that, under the conditions imposed, vitamin B_{12} had no marked sparing effect on the dietary pantothenic acid requirements of the pigs used, since pantothenic acid deficiency symptoms were noted

in animals consuming rations containing 14 mcg. of vitamin B_{12} per pound, which is certainly in excess of the levels generally considered to be required by pigs of the age and weight used.

Summary

Five-week-old weanling pigs in drylot developed pantothenic acid deficiency symptoms on a 14% crude protein basal ration composed of ground corn, soybean oil meal, minerals and supplemented with vitamins, except for pantothenic acid. Supplementation of this ration with either pantothenic acid or chlortetracycline prevented the development of deficiency symptoms.

Pigs initially weighing 16 lb. developed more severe deficiency symptoms than pigs initially weighing 20 lb. Possible explanations for this difference in response are discussed.

Although not a sensitive criterion, concentration of pantothenic acid in the liver seemed to reflect more accurately the pantothenic acid status of the animals than levels of this vitamin in the brain, heart or kidney. Age and ration influenced the liver and kidney level of pantothenic acid.

Under the conditions imposed, chlortetracycline at the level of 10 mg. per lb. of ration appeared to have a sparing effect on the dietary pantothenic acid requirements of weanling pigs.

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STUDIES ON THE UTILIZATION OF UREA BY GROWING SWINE [1]

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THE results of earlier investigations on the utilization of urea nitrogen by the pig have been in disagreement. Grafe *et al.* (1913) reported that urea added to a low protein ration increased nitrogen retention. Piepenbrock (1927) reported 30 to 40% of the protein in swine rations could be replaced by urea without harmful effects. More recent reports by Braude *et al.* (1942) and Hanson and Ferrin (1955) indicate that urea has no place in pig diets. However, the work of Rose *et al.* (1949) with rats would indicate that the monogastric animal has a limited ability to utilize non-protein nitrogen and also work at this station with heavy nitrogen labeled urea by Liu *et al.* (1955) showed that small amounts of the labeled urea nitrogen appeared in the tissue proteins of pigs.

With these reports in mind three experiments were designed to study the utilization of urea nitrogen in a standard corn-soybean oil meal ration, in a low-protein corn-soybean oil meal ration supplemented with DL-methionine and L-lysine, and in a low-protein semi-purified ration in which the protein was of high biological value.

Experimental Procedure

Experiment 626

Forty-eight Poland China × Landrace × Duroc pigs were randomly allotted within weight outcome groups, within sex, to the 12 ration treatments in a two by six factorial experiment. The average initial weight and age were 22.7 lb., and 42.7 days, respectively. The animals were maintained in individual wire floored metabolism cages during the entire experiment. Feed and water were provided ad libitum.

The 12 ration treatments were made up by replacing 0, 2.5, 5, 10, 20, or 40% of the protein equivalent with urea, with or without antibiotic

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(5 mg. chlortetracycline per lb. of ration) supplementation. The urea levels fed to make up the above protein equivalents were 0, 0.16, 0.31, 0.62, 1.25 and 2.45% of the total diet. The quantities of corn, soybean oil meal and urea were adjusted to maintain a 16% protein equivalent (N $\times$ 6.25) in each ration.

Criteria of urea utilization were rate of gain, feed per lb. of gain and nitrogen retention. Weight gains and amount of feed consumed were determined at 14-day intervals until each pig individually reached 100$\pm$5 lb. body weight, or until, in the case of those animals receiving 2.45% urea (40% of protein equivalent), they had been on experiment 84 days.

As the animals individually reached 75 lb. body weight, the feces and urine were collected to measure nitrogen retention. Urine was collected for a 72-hour period, aliquots were taken twice daily and preserved under toluene and refrigeration until analyzed. Fecal collections were made with the use of ferric oxide as a marker given in a capsule at 72-hour intervals; aliquots of the fecal samples were immediately frozen then dried at 100–105° C. at the end of the 3-day collection period. The animals were fed ad libitum and representative samples of the rations were taken at the beginning of the collection period and analyzed to determine nitrogen intake. The excreta and ration samples were analyzed for total nitrogen by conventional Kjeldahl procedures.

Nitrogen balances were determined on the pigs receiving the highest level of urea, 2.45% of total diet, after 77 days and the pigs were sacrificed after 84 days on experiment.

In order that the kidneys and livers of the pigs might be examined for any effects of urea feeding, the pigs were sacrificed as they attained a weight of 100$\pm$5 lb., except for those mentioned in the above paragraph. Blood samples for urea determinations were secured at the time of slaughter which was zero to six hours after removal from the feeding crates. The Van Slyke-Cullen method (Hawk, Oser and Summerson, 1951, p. 501) was used for the analysis of urea in the blood.

Experiment 666

Ten barrow and 20 female Poland China $\times$ Landrace $\times$ Duroc pigs averaging 71.9 lb. body weight and 90 days of age initially were randomly allotted within sex to five ration treatments. Each pen of animals consisted of two pigs. One five-treatment set of pens was made up of barrows and two sets were made using female pigs. The animals were fed and watered ad libitum and remained on experiment for 49 days.

Weight gains and amount of feed consumed were determined at 14-day intervals.

A constant level of 2.6% soybean oil meal and 75.1% corn was used in the first four rations and the ration treatments were made up by replacing starch with urea or amino acids or both. Ration 1 was a low protein (8%) basal ration. Ration 2 consisted of the basal plus 0.65% urea. Ration 3 was the basal supplemented with 0.4% DL-methionine

TABLE 1 COMPOSITION OF RATIONS FOR EXPERIMENTS 626 AND 666

	Experiment 626		Experiment 666	
	Protein equivalent as urea [a]		Calculated crude protein	
Ingredient	0	20	8.0	10.0
	Percentage composition			
Ground yellow corn	72.80	80.00	75.10	84.70
Solvent SBOM [b]	17.70	9.15	2.60	5.20
Starch (corn)			12.15	
Molasses (cane)	5.00	5.00	5.00	5.00
Dicalcium phosphate	1.40	1.60	2.20	2.15
Calcium carbonate	0.50	0.40	0.30	0.30
Salt (iodized)	0.50	0.50	0.50	0.50
Trace mineral premix [c]	0.10	0.10	0.15	0.15
Vitamin premix [d]	2.00	2.00	2.00	2.00
Urea [e]		1.25		

[a] Rations of Experiment 626 calculated 16% crude protein.
[b] A blend of hexane extracted meals from 3 sources.
[c] Supplied the following in p.p.m. Fe, 70; Cu, 4.8; Co, 1.6; Zn, 4.5 and Mn, 59.0. The level used in Experiment 666 supplied 1.5 times the above values.
[d] Supplied the following per lb. diet Experiment 626: Vit. A, 1000 IU; Vit. D_3, 400 IU; Riboflavin, 1.0 mg.; Niacin, 6.0 mg.; Calcium pantothenate, 2.0 mg.; Choline chloride, 170 mg.; Vit. B_{12}, 5 mcg.; Experiment 666: Vit. A, 2000 IU; Vit. D_3, 400 IU; Riboflavin, 1.0 mg.; Calcium pantothenate, 2.4 mg.; Niacin, 7.0 mg.; Choline chloride, 253 mg. and Vit. B_{12}, 5.0 mcg.
[e] Supplied by E. I. duPont de Nemours, Inc.

and 0.25% L-lysine HCl to bring the calculated levels of these amino acids to that in ration 5, a 10% protein corn-soybean oil meal diet. Ration 4 consisted of the basal plus 0.04% DL-methionine, 0.26% L-lysine and 0.65% urea and calculated 10% crude protein. Ration 5 was considered the positive control (10% protein, table 1) and vitamin and trace mineral fortification was the same in all five rations.

Experiment 673

Twelve barrow and 12 female Poland China × Landrace × Duroc pigs averaging 30.8 lb. body weight and 45.6 days of age were randomly allotted within weight outcome groups within sex to the six ration treat-

TABLE 2. COMPOSITION OF RATIONS FOR EXPERIMENT 673

Ingredient	Calculated crude protein					
	8 %			10 %		
	Protein equivalent as urea, %					
	0	10	20	0	10	20
	Percentage composition					
Protein mixture[a]	15.20	13.57	11.46	21.14	18.38	15.79
Starch (corn)	57.60	58.86	60.56	51.97	54.20	56.29
Dextrose	10.00	10.00	10.00	10.00	10.00	10.00
Dicalcium phosphate	1.87	1.97	2.10	1.51	1.68	1.84
Calcium carbonate	0.18	0.16	0.14	0.25	0.22	0.19
Salt (iodized)	0.50	0.50	0.50	0.50	0.50	0.50
Trace mineral premix[b]	1.63	1.63	1.63	1.63	1.63	1.63
Dar-Sta-Fat	2.00	2.00	2.00	2.00	2.00	2.00
Cond. fish solubles	3.00	3.00	3.00	3.00	3.00	3.00
Dried whey	2.50	2.50	2.50	2.50	2.50	2.50
Brewer's yeast	1.00	1.00	1.00	1.00	1.00	1.00
Solka Floc	2.50	2.50	2.50	2.50	2.50	2.50
Vitamin premix[c]	2.00	2.00	2.00	2.00	2.00	2.00
Urea	0.00	0.31	0.61	0.00	0.39	0.76

[a] A mixture of 66% dried skimmilk and 34% dried whole egg.
[b] Supplied the following elements in parts per million: Mn, 100; Fe, 360; Cu, 7.6; Co, 3; Zn, 30; Mg, 500; K, 4000.
[c] Supplied the following vitamins per lb. of diet. Vit. A, 2000 IU; Vit. D, 400 IU; Riboflavin, 0.84 mg.; Calcium pantothenate, 2.2 mg.; Niacin, 9 mg.; Choline, 290 mg.; Vit. B_{12}, 5 mcg.

ments. The animals were kept in individual wire floored pens for an experimental period of 28 days. They were fed ad libitum and watered three times daily. Weight gain and amount of feed consumed were determined at 14-day intervals.

ANALYSIS OF VARIANCE PLANS

Source of variation	Degrees of freedom		
	Exp. 626	Exp. 666	Exp. 673
Replication	1	2	3
All comparisons	19	4	5
Sex	1		
Antibiotic	1		
Amino acid		1	
Protein level		1	1
Urea level	4	1	2
Interactions	13	1	2
Experimental error	18	8	15
All causes	38[a]	14	23

[a] One missing value estimated.

The ration treatments consisted of 8 or 10% protein levels in which 0, 10, or 20% of the protein equivalent was furnished by urea, as presented in table 2. The preformed protein was from a mixture of 66% dried skimmilk and 34% whole dried egg. The starch, protein mixture and urea were adjusted to make up the different ration treatments.

The data of all three experiments were analysed by the method of analysis of variance according to the plans indicated on page 47.

TABLE 3. SUMMARIES OF DAILY GAINS, DAILY FEED AND FEED PER POUND OF GAIN PER PIG FOR EXPERIMENT 626

	Urea (protein equivalent) levels, %[a]					
Antibiotic treatment	0 (0)	0.16 (2.5)	0.31 (5.0)	0.62 (10.0)	1.25 (20.0)	Av.
			Daily gains, lb.[b c]			
None	1.15	1.12	1.14[d]	1.17	0.99	1.11
5 mg. per lb.	1.15	1.25	1.12	1.17	0.87	1.11
Av.	1.15	1.18	1.13	1.17	0.93	
			Daily feed, lb.			
None	2.90	2.76	2.75[d]	3.09	2.80	2.86
5 mg. per lb.	2.82	3.04	2.86	3.00	2.61	2.87
Av.	2.86	2.90	2.81	3.05	2.70	
			Feed per lb. gain, lb.[b]			
None	2.52	2.48	2.42[d]	2.64	2.84	2.58
5 mg. per lb.	2.46	2.43	2.56	2.56	3.01	2.60
Av.	2.49	2.46	2.49	2.60	2.92	

[a] Figures in parenthesis are percent protein equivalent from urea.
[b] Linear regression component significant at P=.05 or less.
[c] Quadratic regression component significant at P=.05 or less.
[d] Average for 3 pigs only.
The individual pig was taken as the experimental unit. The experimental error mean squares for daily gain, daily feed and feed per lb. of gain were 0.01435, 0.08274 and 0.02343, respectively.

Where appropriate, the sum of squares for treatments were partitioned to give the mean squares for the linear, quadratic, etc. regression components (Snedecor, 1956, p. 348). All statements concerning statistical significance in this study pertain to P=.05 or less.

Results

Experiment 626

Summaries of average daily gains, daily feed intakes and feed per lb. of gain are presented in table 3. The eight pigs fed the 40% urea-

protein equivalent ration attained an average weight of only 36 lb. after 84 days on the test. The 40 pigs given the other five urea levels required an average of only 70 days to reach a weight of 100 lb. Because of this marked discrepancy in final weight no direct comparisons will be made with the pigs given the highest level of urea and therefore, their response data have been omitted from tables 3 and 4.

TABLE 4. SUMMARIES OF PERCENT NITROGEN RETAINED, BLOOD UREA AND KIDNEY WEIGHT PER 100 LB. BODY WEIGHT PER PIG FOR EXPERIMENT 626

	Urea (protein equivalent) levels, % [a]					
	0	0.16	0.31	0.62	1.25	
Antibiotic treatment	(0)	(2.5)	(5.0)	(10.0)	(20.0)	Av.
	Percent retained nitrogen [b]					
None	43.8	37.5	36.3[d]	28.3	30.6	35.3
5 mg. per lb.	50.4	41.9	33.2	42.3	37.1	41.0
Av.	47.1	39.7	34.8	35.3	33.9	
	Blood urea (mg. per 100 ml.) [b]					
None	22.5	23.7	23.7[d]	25.1	29.5	24.9
5 mg. per lb.	21.8	23.0	26.8	23.9	29.1	24.9
Av.	22.2	23.3	25.3	24.5	29.3	
	Kidney weight per 100 lb. body weight, gm. [b c]					
None	193	178	178[d]	204	159	182
5 mg. per lb.	194	190	168	188	171	182
Av.	194	184	173	196	165	

[a] Figures in parenthesis are percent protein equivalent from urea.
[b] Linear regression component significant at P=.05 or less.
[c] Cubic regression component significant at P=.05 or less.
[d] Average for 3 pigs only.
The individual pig was taken as the experimental unit. The experimental error mean squares for percent retained nitrogen, blood urea and kidney weights per 100 lb. body weight were 116.0, 10.83 and 304, respectively.

None of the average differences between the non-antibiotic and the antibiotic fed pigs reported in tables 4 and 5 was statistically significant. In several instances the average responses of the two groups of pigs were identical or almost so. In none of the criteria studied was there a significant interaction between the antibiotic treatment and the levels of urea in the ration.

The rates of gain resulting from the first four levels of urea were relatively similar but there was a marked reduction in the rates for the 20% protein equivalent level. The average trend of the gains, however, as measured by the best fitting line was parabolic in nature with the

maximum rate occurring at the 5% protein equivalent level for a daily gain of 1.17 lb. Therefore, the addition of about 0.16 and 0.31% urea to the ration gave slightly increased daily gains but higher levels caused the gains to be much slower.

The differences observed in daily feed intake between the various levels of urea were not statistically significant. There was, however, a statistically significant linear relationship between the urea levels in the rations and feed required per lb. gain. The feed required per lb. of gain increased from 2.49 to 2.92 lb. from the zero to the 20% protein equivalent level of urea.

On the average the addition of urea to the rations resulted in a statistically significant linear decrease in the percent nitrogen retained by the pigs and an increase in the concentration of urea in the blood. The nitrogen retained dropped from 47.1 to 33.9% while the blood urea increased from 22.2 to 29.3 mg. % as the urea in the ration was increased from zero to 1.25% (0–20% protein equivalent).

The values for the kidney weights per 100 lb. body weight varied considerably between the different levels of urea in the ration. They tended to decrease as the level of urea was increased with the exception of a high value of 196 gm. for the pigs on the 0.62% of urea. A careful review of the procedure used and the time sequence involved gave no indication of any circumstance that should have tended to give high values for the kidney weight of these pigs.

Of the 24 interaction mean squares (four for each of the six criteria) only two were statistically significant. They were the second order interaction of sex $\times$ antibiotic $\times$ urea level for the percent nitrogen retention and for the kidney weight per 100 lb. body weight. Detailed examination of the three-way tables of response data showed no consistent trends within or between these two criteria. The authors can not offer a satisfactory explanation on any biological basis for such large interaction mean squares. The fact that each cell in the three-way table contained observations on only two pigs and the high variability of the response data may have been contributing factors to these apparent interactions.

Examination of the kidneys and livers at time of slaughter revealed lesions and considerable congestion in both organs of the pigs that received 2.45% urea in their rations. The veterinarian reported congestion and lesions suggestive of conditions found in septicemic infection and toxemia. No bacteriological examinations were performed. Neither

of these two organs from the other animals revealed any abnormalities that could be associated with ration treatment.

None of the animals died while on experiment, but one pig on the 0.31% urea level failed to grow satisfactorily so it was removed and posted by a veterinarian. Diagnosis revealed lesions similar to those noted above. Bacteriological cultures were negative for any known swine bacterial pathogens.

TABLE 5. SUMMARIES OF DAILY GAINS, DAILY FEED AND FEED PER LB. GAIN PER PIG FOR EXPERIMENT 666

Urea	Lysine+ methionine	Protein	Daily gain	Daily feed	Feed per lb. gain
	Percent			Pounds	
nil	nil	8.0	1.16	4.95	4.30
nil	0.30	8.3	1.07	4.28	4.03
0.65	nil	9.7	1.08	5.01	4.63
0.65	0.30	10.0	1.07	4.66	4.41
Corn	SBOM	10.0	1.69*	6.17*	3.64*
		Main comparisons			
nil			1.12	4.62	4.16
0.65			1.07	4.84	4.52
	nil		1.12	4.98	4.46
	0.30		1.07	4.47	4.22

* Values significantly different from the averages of all the other treatments (P=.05 or less). The pen of two pigs was taken as the experimental unit. The experimental error mean squares for daily gain, daily feed and feed per lb. gain were 0.09531, 0.2200 and 0.08608, respectively.

Experiment 666

Summaries of daily gains, daily feed intake and feed per lb. of gain are presented in table 5. None of the differences in the responses obtained in the several criteria from the addition of urea, the amino acids or the combination of the two was shown to be statistically significant. Neither were there any statistically significant interactions between the urea and amino acid groups. Raising the protein content of the basal ration from 8% to an equivalent of 10% by the addition of urea and amino acids failed to significantly improve either rate of gain or feed efficiency. The enhanced responses of the pigs on the corn-soybean oil meal ration compared to the average of the other four rations were statistically significant for all three response criteria.

Experiment 673

Summaries of daily gain, daily feed intake and feed per lb. of gain are presented in table 6. None of the interactions between the protein and urea levels was statistically significant. The increased levels of urea in the rations resulted in statistically significant linear depressions in rates of gain, of feed intake and of feed efficiency. The higher protein

TABLE 6. SUMMARIES OF DAILY GAIN, DAILY FEED AND FEED PER LB. GAIN PER PIG FOR EXPERIMENT 673

Percent protein equivalent as urea	Percent protein		
	8	10	Av.
		Daily gain, lb.	
0	1.08	1.04	1.06[a]
10	0.80	0.98	0.89
20	0.71	0.89	0.80
Av.	0.87*	0.97	
		Daily feed, lb.	
0	2.74	2.46	2.60[a]
10	2.35	2.42	2.38
20	2.29	2.46	2.38
Av.	2.46	2.45	
		Feed per lb. gain, lb.	
0	2.54	2.38	2.46[a]
10	2.92	2.46	2.69
20	3.28	2.78	3.03
Av.	2.92*	2.54	

[a] Linear regression significant at P=.05 or less.
* Averages for protein levels significantly different at P=.05 or less.
The individual pig was taken as the experimental unit. The experimental error mean squares for daily gain, daily feed and feed per lb. gain were 0.01173, 0.04131 and 0.06667, respectively.

level gave statistically significantly greater gains and lower feed per lb. of gain but gave almost identical daily feed intakes. The daily gains for the zero level of urea were also almost identical and the feed per lb. gain was not statistically different for the two levels of protein, indicating this level of protein is sufficient when the ration protein is made up of dried skimmilk and whole dried egg.

Discussion

The work of Rose *et al.* (1949) demonstrated that rats are able to utilize non-protein (urea) nitrogen to meet a portion of their nitrogen

requirement provided that the essential amino acids requirements are first met. Also the previously mentioned work of Liu *et al.* (1955 showed that small amounts of urea nitrogen are incorporated into the tissue proteins, however, their work does not demonstrate a net gain in nitrogen to the animal. Whole dried egg and dried skimmilk were used as a source of protein in experiment 673 in an attempt to meet the essential amino acid requirements and still have a sub-optimum protein level in the diet. It was realized that there were substantial quanities of the non-essential amino acids present and therefore the rations were not strictly comparable to those used by Rose *et al.* However, an experiment of this order more nearly approaches the practical possibilities of non-protein nitrogen utilization than does the use of amino acid mixtures. Eight percent protein from this mixture appeared to be border line in adequacy though it resulted in gains equal to the 10% protein diet, the feed conversion was not as efficient. Also, as can be seen in table 6, the detrimental effect of urea substitution was more severe for the 8% rations than for the 10% even though the level of urea was higher in the 10% protein rations.

The results of experiment 626 coupled with the results of experiment 673 indicate the harmful level of urea to be between 0.62 and 0.76% of the total diet, provided the preformed protein level is adequate. Levels lower than this may slightly decrease feed efficiency or rate of gain but does not appear to be detrimental to the general well being and health of the animal. Only the 2.45% level of urea in the ration was severely detrimental to the growth of animals, however, this level was not fatal.

Summary

The results of three experiments indicate that urea has no place in practical swine rations. Low levels of urea of 0.16 and 0.31% of the ration exerted no harmful effect on gains; slightly improved gains were obtained at these levels, however, feed required per lb. of gain increased linearly as urea increased from 0.0 to 1.25% of the diet. Also percent nitrogen retained decreased as the level of urea in the diet was increased.

The addition of 0.65% urea or, 0.04% methionine and 0.26% lysine or a combination of the urea and amino acids failed to significantly improve an 8% protein corn-soybean oil meal type ration in respect to rate of gain or feed conversion.

The replacement of 10 or 20% of the protein with equivalent amounts of urea nitrogen, in diets containing 8 or 10% total protein from a mixture of whole dried egg and dried skimmilk, significantly decreased the rate of gain and increased the feed required per pound of gain. The decreased performance was more severe on the lower level of protein

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THE EFFECT OF ADDED SUCROSE ON THE DIGESTIBILITY OF PROTEIN AND FIBER BY SWINE

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SUGAR has been used with success in swine rations, especially in starters for young pigs (Diaz *et al.*, 1956). Because of its high solubility, sugar might be expected to be completely digested and absorbed, but the problem has not been studied with swine. The addition of 15% or more of sugar or molasses to the ration of ruminants results in a depression of digestibility of the crude fiber and crude protein (Hamilton, 1942). In 1953, Skipitaris, at the University of Thessaloniki in Greece, observed that the addition of carob pod meal to a barley ration depressed the digestibility of the crude protein in the ration by swine. Since the carob pod meal contained 35 to 40% sucrose and reducing sugars, this result suggested that excess sugar may decrease the digestibility of certain nutrients in feeds for swine, as has been observed with sheep and cattle. Mitchell (1942) reported, however, that such pronounced associative effects have been noted only with ruminants.

Digestion experiments were carried out to study the influence of added sugar on the digestibility of crude protein and crude fiber by swine.

Experimental Procedure

Four barrows, two Yorkshires weighing 215 and 208 lb. and two Berkshires weighing 164 and 154 lb. were used in 16 digestion trials. Table 1 shows the plan of the study and the feed intakes during the four experimental periods. The design was a modified latin square suggested by Henderson (1955) and allowed for an estimation of the carry over effects.

During the basal periods the larger pigs were fed a constant amount of 1800 gm. daily of barley, ground to a fine meal, supplemented with vitamins and minerals, and the smaller pigs received 1600 gm. daily. Table grade sucrose was added at a level of 16% during the other periods without lowering the barley allowances. These levels of intake

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[2] The assistance of H. W. Seeley is acknowledged for helpful suggestions in carrying out the experiment and in reading the manuscript.

were established during a pre-experimental period of two weeks. There were no feed refusals during the trials. The basal barley ration supplied approximately 60% of Morrison's TDN standard for growing and fattening pigs of these body weights. The pigs gained 0.64 to 0.67 lb. daily during the experimental periods. A 10-day preliminary and a 7-day collection period made up each trial. The feed for each period was carefully mixed and the allowance for each feeding was weighed into a paper bag at the start of each period, samples being saved at the same time for chemical analyses.

The pigs were kept in metabolism crates similar to those used by Crampton and Whiting (1943). They were fed twice daily at 8.30 a.m.

TABLE 1. THE FEEDING SCHEDULE OF PIGS RECEIVING GROUND BARLEY WITH AND WITHOUT ADDED SUCROSE

	Feed intake, grams per day							
	Period I		Period II		Period III		Period IV	
Pig No.[a]	Barley[b]	Sucrose	Barley	Sucrose	Barley	Sucrose	Barley	Sucrose
1Y	1800	288	1800	288	1800		1800	
2B	1600	256	1600		1600		1600	256
3Y	1800		1800		1800	288	1800	288
4B	1600		1600	256	1600	256	1600	

[a] Y is for Yorkshire and B for Berkshire.

[b] The barley was ground and supplemented with vitamins and minerals to furnish the amounts recommended by Beeson *et al.* (1953). Zinc was added at a level of 4 ppm of the barley, the final barley meal fed contained 10.90% and 4.91% of crude protein and crude fiber, respectively.

and 5:30 p.m. The feed was mixed into a thick slop and water was allowed *ad lib.* after feeding. The cages permitted the complete collection of feces without contamination with urine. The feces were collected twice daily, weighed and a 7% aliquot placed in a tightly closed glass jar with 1% of thymol and stored at approximately 40° F. At the end of the collection period, the daily aliquots were composited, mixed and a subsample used for chemical analyses. Nitrogen was determined on the fresh feces by the Kjeldahl method. Crude fiber was determined by the A.O.A.C. method.

Bacterial protein in the feces was determined by a modification of the method of Mattill and Hawk (1911) using a series of fractional sedimentations in a high-speed centrifuge. Dilute HCl solution (0.2%) was used to free the bacteria of fecal residues as described in detail by Skipitaris (1956). The crude protein fractions studied are described in table 2.

Counts were made of the total fecal bacteria by the nigrosine slide

TABLE 2. THE RESULTS OF THE MICROSCOPIC EXAMINATION OF VARIOUS COMPONENTS OF FECAL PROTEIN OF SWINE SEPARATED BY FRACTIONAL CENTRIFUGATION

Fractionation designation[a]	Approx. No. of gs.[b]	Centrifugation time	Microscopic observation
		min.	
1. Residue protein	230	1	Fecal particles protozoa, few bacteria
2. Bacterial protein	10800	20	Bacteria, traces of fecal debris
3. Soluble protein	Supernantant From no. 2		Free of cells and debris

[a] N×6.25.
[b] No. of times gravity.

technique described by Gall *et al.* (1947, 1949). A 0.01 ml. sample of the carefully mixed bacterial suspension was transferred by a Breed pipette to a slide and mixed with a 3 mm. loopful of a saturated methyl alcohol solution of nigrosine. The mixture was spread evenly on the slide and dried on a hot plate. Counts were made of 20 fields on each of two slides made from duplicate samples from each period. The bacterial counts, the slide area and volume, the volume of bacterial suspension and its relation to total feces being known, it was possible to estimate the total bacteria excreted on each diet.

The method used in calculating the analysis of variance is shown in table 3.

Results and Discussion

The average apparent digestion coefficients are shown in table 4. It is evident that the added sucrose depressed the digestibility of the crude

TABLE 3. METHOD USED FOR ANALYSIS OF VARIANCE

	d.f.	SS
Total	15	Computed in usual way
Pigs	3	Computed in usual way
Periods	3	Computed in usual way
Treatments, direct	1	$(T_a—T_b)^2/16$
Treatments, residual	1	$(R_a—R_b)^2/12$
Error	7	By difference

T_a = total for treatment A.
T_b = total for treatment B.
R_a = total of the 6 observations preceded by A.
R_b = total of the 6 observations preceded by B.

protein and crude fiber. This depression amounted to approximately 5% and 38% for crude protein and crude fiber, respectively. The differences were highly significant ($P<0.01$). The marked decrease in digestibility of crude fiber is probably the result of intestinal bacteria utilizing the sugar for energy in place of fiber, as occurs in ruminants. It is possible that the depression in crude fiber digestibility increased the loss of protein in the feces because of the less complete digestion of "fiber-bound" protein. The bacterial population was greater on the

TABLE 4. THE AVERAGE APPARENT DIGESTION COEFFICIENTS OF PROTEIN AND CRUDE FIBER OF SWINE RECEIVING BARLEY WITH AND WITHOUT ADDED SUCROSE

	Ration				
	Barley		Barley+Sucrose		
Pig. No.	Protein	Crude fiber	Protein	Crude fiber	Corrected protein[a]
1Y	76.8	16.4	73.0	11.0	74.0
2B	75.6	15.0	70.8	9.2	72.4
3Y	77.8	17.8	74.2	10.6	76.2
4B	76.0	16.5	72.1	10.0	74.0
Av.	76.6	16.4	72.5**	10.2**	74.2**

[a] Corrected for lower digestibility of crude fiber.
** Significantly lower than barley alone ($P<0.01$).

sugar ration and these bacteria carried additional nitrogen into the fecal excretions.

Presented also in table 4 are coefficients for protein digestibility of the barley plus sucrose ration corrected for the lowered digestibility of crude fiber. This calculation was based on the assumption that the increase in fecal crude fiber accompanying sucrose feeding, resulted in a proportionate increase in fecal protein. The corrected protein digestion coefficient thus reflects the *maximum* theoretical amount of fecal protein which could have resulted from the increased excretion of "fiber-bound" protein. The corrected digestion coefficients remain lower than those for the protein in barley fed alone, supporting the view that increased bacterial growth on the barley plus sucrose effected a lowered apparent digestibility of dietary nitrogen by the pig.

The average crude protein contents of the various fecal fractions are shown in table 5. For each pig, the feces contained more nitrogen when the ration contained added sucrose. The differences were highly significant ($P<0.01$) for each fraction of the fecal crude protein as well as for the total fecal protein. It is possible that a portion of the residual

and soluble protein may have been the result of an increase in metabolic fecal nitrogen as a result of sucrose feeding. The highly soluble nature of the sucrose would suggest that this effect does not exist.

Bacterial counts made on the fecal samples by the nigrosine slide technique gave larger total numbers of bacteria excreted on the diets containing sucrose than on barley alone. The average values were 156×10^{12} on barley plus sugar and 126×10^{12} on barley. In every instance the feces contained more bacteria when sugar was fed. Although the counting techniques may be less accurate than one might desire it

TABLE 5. AVERAGE CRUDE PROTEIN CONTENT OF FECAL FRACTIONS OF PIGS RECEIVING RATIONS WITH AND WITHOUT ADDED SUCROSE

Pig No.	Ration	Crude protein fraction[a]			Total protein[a]
		Residue	Bacterial	Soluble	
		gm.	gm.	gm.	gm.
1Y	Barley	80	144	94	318
	Barley+sugar	86	166	118	370
2B	Barley	74	132	96	302
	Barley+sugar	82	156	120	358
3Y	Barley	90	136	74	300
	Barley+sugar	102	150	100	352
4B	Barley	80	136	79	295
	Barley+sugar	84	154	102	340
Av.	Barley	81	137	86	303
	Barley+sugar	88	157	110	355

[a] N×6.25.

is interesting that the total bacterial counts support the other data in suggesting that the addition of 16% of sugar to barley increases the fecal bacteria and at the same time lowers utilization of both the crude protein and the crude fiber.

It is evident from the data that the addition of sugar to the ration of pigs lowers the digestibility of both the protein and the crude fiber in about the same way as is true for ruminants. The decreases in the digestion coefficients, appear to be similar in magnitude to those reported for ruminants. Briggs and Heller (1943) observed that 25% of cane molasses added to a ration for sheep lowered the digestibility of the crude protein by 6.5%. Hamilton (1942), using sheep, obtained depressions of 12% for crude protein and 27% for crude fiber in a ration containing up to 30% of glucose.

From a practical standpoint, the depressed digestibility of crude fiber

resulting from the addition of sucrose appears to be of less importance in swine rations than in ruminant rations, at least in terms of the availability of energy, because of the lower content and poorer utilization of the fiber under all conditions. The results suggest that a ration for growing-fattening swine which contains as much as 16% of sugar should be higher in protein to compensate for its lowered digestibility. The depression in digestibility of crude fiber presumably would be of greatest importance for sows maintained on large amounts of silage or for pigs on pasture; obviously, the question should be studied.

The statistical analysis of the data showed that the mean square for carry over effect was negligible. It can be inferred from this observation that for a study of digestibility and/or bacterial changes a preliminary period of 10 days is completely satisfactory and in all probability longer than is absolutely necessary.

Summary

Studies were conducted with pigs to measure the influence of added sugar upon the digestibility of the crude protein and the crude fiber of barley. Adding 16% of sucrose lowered the apparent digestibility of the crude protein and the crude fiber approximately 5% and 38%, respectively. The depression of protein digestibility was found to be greater than could be explained by an increase in the excretion of "fiber-bound" protein. Fecal nitrogen fractionation revealed more nitrogen present as bacteria, as soluble nitrogen and residual nitrogen when sucrose was added than when barley was fed alone. The depression in digestibility of protein and crude fiber as the result of feeding sugar seems to be similar in magnitude to the depressions observed with ruminants.

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RELATIONSHIP OF PLASMA LIPID LEVELS TO CARCASS QUALITY AND RATE OF GAIN IN SWINE [1]

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A BLOOD constituent that could be determined easily and that would yield a high and predictable correlation with measurements of carcass quality or with rate of gain in livestock would aid research workers in animal nutrition and breeding. Such a determination would be most valuable if it was highly repeatable and could be performed at an early stage in the animal's life. In general, live animal measurements have not been good indicators of production or carcass traits. An exception has been the use of backfat probing techniques in swine (Hazel and Kline, 1952; Hetzer *et al.*, 1956; and Berg and Bowland, 1956) where good correlations were found with carcass measurements.

Several groups of workers have suggested that distinctive metabolic traits are characteristic of certain individuals or breeds (Williams *et al.*, 1949; Kunkel *et al.*, 1954; and Bunding *et al.*, 1956). In cattle, Lofgreen and Garrett (1954) carried this suggestion one step further when they reported that creatinine excretion per unit of body weight was significantly correlated with percent separable lean.

It would seem reasonable that one physiological indicator that might be related to carcass quality (lean to fat ratio) and to potential gain in swine would be blood plasma lipid levels. This paper presents the results of a series of studies on the relationship of plasma lipid levels to various carcass measurements as well as to rate of gain in market pigs.

Experimental

During 1952 to 1955, four groups of purebred Yorkshire pigs at the University of Alberta Livestock Farm were used for the plasma lipid studies. Fifteen-ml. samples of blood were drawn from 121 pigs when they were approximately 100 lb. in weight, while in the case of 32 pigs (group 4) a second bleeding was carried out at market weight. The blood was obtained from the anterior vena cava by the method described

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by Carle and Dewhirst (1942) using potassium oxalate as an anti-coagulant. Following centrifuging, the lipid content of the plasma was determined in duplicate by the volumetric method of Allen (1934).

The rations fed in all experiments were typical of those routinely used in western Canada consisting of barley and oats with a supplement of soybean oil meal, meat scrap, alfalfa meal, iodized salt, ground limestone, vitamins A and D plus an antibiotic feed supplement in some cases. The fat content of these rations was relatively low, being calculated as under 4%. The pigs were self-fed in a barn on concrete floors.

In 2 experiments (groups 1 and 2) consisting of a total of 53 pigs, blood samples were obtained without removing the pigs from access to feed. In the other 2 experiments (groups 3 and 4) the 68 pigs were fasted for a period of 16 to 18 hours before bleeding so that they approached a post-absorptive state. These 2 treatments will be analyzed and discussed separately.

The pigs were marketed at a live weight of 200±10 lb. with cutting and measurement of the carcasses being carried out by Canadian Advanced Registry for Swine standards.[4] The measurements considered in this study were: (a) maximum shoulder fat, (b) minimum backfat taken near the last rib, (c) maximum loin fat, (d) Advanced Registry fat score based on depth and balance of the fat at 3 points of measurement with a maximum possible score of 20, (e) planimeter area of longissimus dorsi muscle at cross section of the middle cut at the last rib. These measurements were taken on the cold carcasses following approximately 48 hr. chilling. The rate of gain figures are based on average daily gain in pounds from an initial weight in the range of 35 to 45 lb. to market weight.

Results and Discussion

The means together with their standard errors for the various items studied are shown in table 1. Table 2 gives the correlation coefficients of the plasma lipid determinations when the pigs were 100 lb. in weight with measurements of fat and loin area at market weight as well as with average daily gain.

As indicated by the means shown in table 1, the average carcass quality based on the measurements taken was similar for the fasted and the non-fasted pigs so that a comparison of results should be legitimate. In the first experiments, carried out with 53 pigs which were

[4] Acknowledgement is made of the assistance of the Production Service and Marketing Service, Canada Department of Agriculture, in cutting and measuring carcasses.

TABLE 1. MEANS AND STANDARD ERRORS OF VARIABLES IN PLASMA LIPID STUDY

Variables	Treatment							
	Not fasted		Fasted		Fasted group 4 [a]		Summary all pigs	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
No. of pigs	53		68		32		121	
Av. liveweight when bled, lb.	98.6	2.14	100.4	1.70	102.8	2.04	99.6	1.55
Av. market weight, lb.	199.7	.26	200.5	.17	199.3	.25	200.2	.15
Av. fat measurements								
Shoulder, in.	2.04	.08	1.98	.07	1.99	.11	2.01	.05
Back and loin, in.	1.26	.06	1.24	.06	1.27	.10	1.24	.04
Back, loin and shoulder, in.	1.51	.05	1.48	.06	1.51	.10	1.49	.04
Av. A.R. fat score (max. 20)	7.4	.83	10.1	.82	9.2	1.13	8.9	.60
Av. area of loin, sq. in.	3.44	.17	3.65	.19	3.98	.23	3.56	.13
Av. daily gain, lb.	1.59	.10	1.47	.09	1.52	.13	1.52	.07
Plasma lipid levels								
100 lb., mg. %	139	4.7	96	6.0	130	4.1	115	4.4
Market weight, mg. %					131	3.8		
r (100 lb. and market weight)					.70			

[a] This group was also bled at market weight for the determination of plasma lipids.

left on feed prior to bleeding, plasma lipid levels at 100 lb. in weight were not correlated to a significant degree with shoulder fat, Advanced Registry fat score, area of loin muscle, or average daily gain. Plasma lipids were significantly correlated with the average back and loin fat or the average of 3 fat measurements at the shoulder, back and loin. Considering all correlation coefficients it appears that plasma lipids taken at 100 lb. in weight from non-fasted pigs would be of little predictive value in relation to carcass quality or rate of gain.

It is recognized that plasma lipid levels are to some extent a reflection of diet, as shown by Bender and Maynard (1934). Even though the rations used in these experiments were low in fat it is possible that a

TABLE 2. RELATIONSHIP OF PLASMA LIPID LEVELS AT 100 LB. WITH CARCASS MEASUREMENTS AND RATE OF GAIN

		Correlation coefficient of plasma lipids with					
Treatment		Shoulder fat	Back and loin fat	Back, loin, and shoulder fat	A.R. fat score	Area of loin	Av. daily gain
Not fasted	r_{xy}	.16	.27*	.30*	—.11	—.0[illegible]	.05
Fasted	r_{xy}	.40**	.30*	.36**	—.22	—.26*	.23

* Significant at 5% level.
** Significant at 1% level.

differential in the time that individual pigs ate prior to bleeding might influence blood lipid levels. For that reason a second series of 2 experiments with a total of 68 pigs was conducted in which the pigs were fasted 16 to 18 hr. prior to bleeding. In this manner the ration *per se* should have had a limited effect on the circulating plasma lipids as the animals would be approaching a post-absorptive state.

In the fasted pigs, the level of plasma lipids was positively correlated with shoulder fat, back and loin fat, and 3 fat measurements combined, and negatively correlated with loin area to either a significant or highly significant extent. The negative correlation of plasma lipids with Advanced Registry fat score and positive correlation of the former with average daily gain approached significance at the 5% level. All correlations were increased as compared to those obtained in earlier experiments with non-fasted pigs. It would appear that where feed is withheld for 16 to 18 hours there is in pigs a definite metabolic individuality of plasma lipid levels which is related to the carcass quality and rate of gain of each animal.

In the 32 fasted pigs from group 4, determinations of plasma lipids

were made at market weight as well as at 100 lb. in weight. The correlation of these two readings was 0.70. This is a highly significant correlation coefficient indicating a relatively high level of repeatability in blood lipid determinations on fasted pigs. Although the correlations of plasma lipids with the various fat measurements and rate of gain were slightly higher for the market weight bleeding than for the 100 lb. bleeding, the correlation of plasma lipids with loin area was reduced and there was no evidence of any real increase in precision in relationships obtained from the second bleeding.

Though the plasma lipid levels do not show as much accuracy as indexes of carcass quality or rate of gain as might be desired, they do show a relationship, highly significant or significant in several cases, to these characteristics. As the measurement can be taken at 100 lb. in weight, plasma lipid levels could be a useful adjunct to visual appraisal or any other method available in estimating performance and carcass characteristics of market hogs. It has been noted in beef cattle by Kunkel *et al.* (1954) that breed differences as well as individual differences may occur in at least one blood constituent, glutathione. As the study reported here was restricted to Yorkshire swine, it must be realized that such breed differences may occur in plasma lipid levels in swine.

Summary

When pigs were not fasted prior to bleeding, there was a significant correlation between plasma lipid levels taken at 100 lb. in weight and average backfat thickness, but no appreciable correlation of plasma lipid levels with loin area or rate of gain. Following a 16- to 18-hour fasting period prior to bleeding so that the pigs were allowed to approach a post-absorptive state, there were significant or highly significant correlations of plasma lipids with shoulder fat, back and loin fat, combined shoulder, back and loin fat, and area of loin muscle, while plasma lipid correlations with average daily gain approached significance at the 5% level. A correlation of .70 was found between plasma lipids taken from individuals at 100 lb. and at 200 lb. liveweight.

The results indicate that plasma lipid levels taken from pigs weighing approximately 100 lb. would be of some use to supplement other measures in estimating fat and lean content of pig carcasses at market weight. In individual fasted pigs, the relationship of plasma lipids to rate of gain is sufficiently high to indicate some physiological relationship.

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INFLUENCE OF CHANGING THE KIND OF FAT IN THE DIET AT VARIOUS WEIGHT INTERVALS ON CARCASS FAT CHARACTERISTICS OF SWINE [1]

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INVESTIGATIONS have shown that increased feed efficiency results when fat is added to the diets of cattle (Matsushima and Dowe, 1954; Willey *et al.*, 1952); dogs and chickens (Schweigert and Siedler, 1954); chicks and turkey poults (Sunde, 1954); and hogs (Kropf *et al.*, 1954; Barrick *et al.*, 1953; and Robison, 1943). Because the composition of the body fat in carcasses of meat animals is influenced by the feed ingested, some kinds of fats cause soft pork (Garton *et al.*, 1954; Barrick *et al.*, 1953; Ellis, Rothwell and Pool, 1931; Ellis, 1926; and Ellis and Isbell, 1926). Several workers, however, have found that feeds producing soft pork carcasses may be fed until the hogs weigh about 100 lb. provided that at this time they are replaced by a feed that will, upon continued feeding to market weight, produce firm carcasses (Hostetler and Halverson, 1940; Ellis and Isbell, 1926).

In recent experiments by Garton *et al.* (1954), Kropf *et al.* (1954) and Barrick *et al.* (1953) high fat diets (10 to 15%) were successfully fed to fattening swine. In view of these reports it was considered likely that soft pork fat could be satisfactorily hardened in a shorter feeding period on rations high in fat than by the use of the feeds reported earlier. Since Barrick *et al.* (1953) showed that diets containing coconut oil as a source of fat produced hogs with extremely hard carcasses, coconut oil was the test fat used in this experiment. This study was undertaken to evaluate the hypothesis that soft pork fat may be satisfactorily hardened by short term feeding of coconut oil and was the basis for conducting this study.

Experimental Procedure

Twenty weaned pigs averaging 45 lb. were randomly assigned and equally divided into five groups and individually fed from self-feeders.

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[2] John Morrell and Co., Ottumwa, Iowa.

[3] Acknowledgment is made to Buckeye Cotton Oil Division of the Buckeye Cellulose Corporation for supplying the soybean oil and coconut oil used in this experiment.

Four groups were fed a basal ration consisting of ground yellow corn, 56.9%; soybean meal, 24.4%; soybean oil, 10%; dehydrated alfalfa meal, 5%; steam bone meal, 2%; limestone, 0.7%; trace mineral salt, 0.5% and antibiotic and vitamin pre-mix, 0.5%. Three of these groups were fed the basal ration until the pigs weighed 125, 150 and 175 lb. respectively, at which time the soybean oil was replaced by an equal quantity of coconut oil; the remaining group received the basal ration during the entire feeding period and served as one of the control groups. The fifth group was fed the basal ration except coconut oil was added in place of soybean oil.

All hogs were slaughtered when they reached a live weight of 200 to 225 lb., and after chilling for 48 hours at 35° F. (1.7° C.) each carcass was given a manual firmness rating designated by one of the following descriptive terms: soft, medium soft, medium firm and firm.

From samples of backfat, iodine numbers were determined by the Hanus method (A.O.A.C., 1950), and oleic, linoleic, linolenic and arachidonic acids were determined according to the method of Mitchell *et al.* (1943) as modified by Brice *et al.* (1952). The percent saturated fatty acids were then determined by difference.

In order to determine the fat stability of each carcass, the bellies were cured according to an accepted dry curing procedure and stored without smoking at approximately 85° F. (29.4° C.) by suspending each bacon from a wire rack under similar conditions with respect to heat and light. Each bacon was sampled every 7 days by removing three slices 5mm. thick and analyzing each slice separately for peroxide content (Stansby, 1941). Rancidity was set as the length of time necessary for all three slices to reach a peroxide value of 40 or more, expressed in milliequivalents of peroxide per kilogram of fat, for any one sampling period.

Results and Discussion

The manual firmness ratings (table 1) for the carcasses showed that the animals receiving soybean oil (control) as a source of fat produced soft carcasses as expected. A uniform hardening process consistent with the length of feeding period on coconut oil is readily ascertained by observing the ratings for the remaining groups. The carcasses in the 175 lb. group were not sufficiently firm to grade as top quality market hogs and were rated as medium soft. The average total gain on coconut oil for this group was only about 32 lb., thus, the feeding period of about 18 days was insufficient to adequately harden the fat. In the

150-lb. group three carcasses were rated medium firm, satisfactory with respect to firmness for market requirements, while the other carcass was rated firm. This group had an average total gain on coconut oil of about 55 lb. in a feeding period of approximately 30 days. It appears, therefore, that about the last month or the last 55 lb. of weight on a ration containing 10% coconut oil or a fat of similar composition is sufficient to satisfactorily harden the fat of hogs fed until this time on a softening fat.

In the 125-lb. group, two carcasses were rated firm and the other two medium firm. The group continuously fed on coconut oil was com-

TABLE 1. FAT CHARACTERISTICS OF HOGS FED SOYBEAN OIL TO 3 DIFFERENT WEIGHTS AND THEN COCONUT OIL TO AVERAGE WEIGHTS OF 205 LB.

Item	Weaning to 205 lb.	Weights started on coconut oil, lb.			Weaning to 205 lb.	Treatment Differences
	Soybean	175	150	125	Coconut	Probability of chance occurrence
Manual firmness[a]	S.	M.S.	M.F.	M.F.–F.	F.	
Iodine No.	93.57	80.56	72.66	67.30	54.25	.01
Oleic acid, %	34.29	36.30	36.34	38.16	37.78	N.S.
Linoleic acid, %	28.84	22.17	18.68	15.72	9.65	.01
Linolenic acid, %	3.26	2.38	1.80	1.60	0.75	.01
Arachidonic acid, %	0.49	0.48	0.38	0.32	0.23	.05
Saturated acids, %	33.12	38.68	42.81	45.21	51.60	.01

[a] S., Soft; M.S., Medium Soft; M.F., Medium Firm; M.F.–F., Medium Firm–Firm; F., Firm.

posed of carcasses of which all were rated as firm. These carcasses were much firmer than carcasses in the other groups or than those usually produced with corn. Support for this statement is shown by the low iodine number of the fat for this group. Because of the hardness of fat, fabrication of these carcasses into cuts was much more difficult than is usually the case.

When the cuts from the coconut-oil-fed hogs were allowed to remain for an hour or more at 80° F. (26.7° C.) they softened very considerably. This behavior is somewhat similar to that of coconut oil which solidifies at 70–77° F. (21.1–25° C.) and melts at 75–80° F. (23.9–26.7° C.). While it is recognized that all pork fat becomes softer with increasing temperature, the marked variation here in degree of hardness when the temperature was fluctuated, is noteworthy.

The fatty acid composition (table 1) and iodine numbers are in close agreement with the manual firmness scores. Iodine number and the unsaturated fatty acid values vary inversely with the length of feeding period on coconut oil. Analysis of variance (Snedecor, 1945) computa-

tions gave significant differences between treatments at the .01 level for iodine number, linoleic acid and linolenic acid. Arachidonic acid was significant at the .05 level but oleic acid was not significant at this level. Correlation coefficients for linoleic, linolenic, arachidonic and oleic acids with iodine number were +.85, +.78, +.55 and —.05 respectively. The oleic acid, therefore, was apparently not an influential factor in contributing to softness or hardness of fat in this study. This finding is in general agreement with the work of Ellis *et al.* (1926).

It is interesting to note the consistency of the oleic acid content in the body fat from the hogs fed the several diets, especially in view of the fat that soybean oil contains approximately 32% oleic acid, while coconut oil contains only about 8%. Yet, the amount of oleic acid of the body fat increased slightly when coconut oil was substituted in the diet for soybean oil. This suggests that oleic acid as a component of the diet does not appreciably influence the level of this fatty acid in the depot fat. However, unpublished work conducted at this station in which oleic acid, as free acid, was fed to hogs as the only source of added fat, indicated that the oleic acid content of body fat may be increased if fed in this form. The stearic and palmitic acid content of the two oils fed are nearly the same, therefore, a conversion to oleic acid from these two fatty acids seems unlikely. It is possible that the oleic acid level is maintained primarily through synthesis from carbohydrate material contained in the basal diet.

The hardening effect produced in the body fat of the hogs by feeding coconut oil was probably accomplished through the utilization of the short chain saturated fatty acids. In this category, coconut oil contains about 79%, of which 65% is composed of lauric and myristic acid and 7% each of caprylic and capric acid. The saturated fatty acids were not individually determined, therefore, the form in which these fatty acids were deposited in the fat is unknown.

Only small inconsistent differences were noted for back fat thickness and percent lean cuts (table 2). Loin areas decreased rather consistently with increase in length of feeding period on coconut oil, but this difference is not regarded as significant with respect to treatments. All groups had about the same daily rate of gain, 1.75 lb., irrespective of the kind of fat fed.

The results of the fat stability test (table 2) support the results obtained for the fatty acid determinations. Carcasses from hogs continuously fed soybean oil were the least stable and those from the hogs continuously fed coconut oil were the most stable. The other groups fell in between these two extremes, with the exception of one bacon in the

125-lb. group that became rancid very early in the storage period and thus lowered the apparent fat stability for this group. It is possible that this bacon either became contaminated with a pro-oxidant such as a heavy metal or that the natural antioxidants present in the fat were lower than in the bacons coming from the other hogs. The fatty acid values for the fat of this one carcass gave no indication that rancidity

TABLE 2. CARCASS MEASUREMENTS OF HOGS FED SOYBEAN OIL TO SEVERAL WEIGHTS FOLLOWED BY COCONUT OIL

Hog weights on each fat diet	Back fat thickness	Lean cuts	Loin area [a]	Days to rancidity
	in.	%	Sq. in.	
Soybean oil (45–205)	1.83	43.35	8.66	9
Coconut oil (175–205)	1.85	42.66	8.24	11
Coconut oil (150–205)	1.69	43.70	7.82	[b]
Coconut oil (125–205)	1.74	42.85	7.42	20
Coconut oil (45–205)	1.76	45.26	7.75	[b]

[a] Total lean area of exposed muscle when cut between third and fourth lumbar vertebrae.
[b] Not rancid in 42 days.

development was due to fat composition and the fatty acid composition and manual firmness scores did not compliment the fat stability test. With this one exception, the statement made earlier to the effect that 150-lb. hogs with soft fat may be satisfactorily hardened if fed a diet containing 10% coconut oil or a fat of similar composition to obtain the last 55 lb. of gain appears to be valid. In this experiment the time required to make this gain was 30 days.

Summary

Twenty hogs were divided into five groups of equal numbers of which four groups were fed a soft fat producing basal diet containing 10% soybean oil. Three groups were fed to varying specified weights at which time coconut oil, a hardening oil, replaced the soybean oil until the hogs reached slaughter weight. The fourth group received soybean oil from weaning weight to market weight, while the fifth group received coconut oil for the same period. When the hogs were fed coconut oil

from weights of 150 to 205 lb. during the last 30 days of the fattening period, carcasses were satisfactory in firmness.

Determinations made on the fat showed decreases in iodine number as the length of feeding period on coconut oil increased. Decreases were similarly found for linoleic, linolenic and arachidonic acids. Fat stability tests conducted by determining periodically the peroxide values on stored cured bacons of each carcass supported the fatty acid composition values and manual firmness scores.

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THE INFLUENCE OF CHLORTETRACYCLINE SUPPLEMENTATION OF THE RATION ON DISTRIBUTION, QUANTITY AND QUALITY OF FAT DEPOSITED IN SWINE I. METABOLIC EFFECTS IN RELATION TO CARCASS COMPOSITION [1, 2]

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IN recent years many workers have reported on the effect of antibiotics in swine rations. Growth rate, feed efficiency, and carcass characteristics have been studied and reported. However, there is a dearth of information on the effect antibiotics may have on the kind of fat deposited in swine. There is likewise very little information in the literature on the effect of antibiotics on the blood fat levels. The possibility that antibiotics may play a part in fat metabolism of the monogastric animal cannot be ruled out.

The objectives of this experiment were: 1. To determine the effect of chlortetracycline supplementation of the ration on the composition, quantity, and quality of fat deposited in swine; 2. To determine the effect of chlortetracycline upon fat metabolism; and 3. To determine the effect of chlortetracycline upon the physical and chemical composition of swine carcasses.

Experimental Procedure

Forty-eight weanling pigs of a Yorkshire, Chester White, Duroc cross, weighing from 28 to 30 lb. were stratified as to sex and randomly assigned to two lots of 24 pigs each (designated as Lot I and Lot II). From each lot six pigs (3 barrows and 3 gilts) were removed at 85, 125, 165, and 205 lb. live weight. Lot I received a basal ration of corn, soybean oil meal, alfalfa leaf meal, and tankage, which was calculated to contain 15, 12.5, and 10% protein for periods 29 to 70, 71 to 125, and 126 to 205 lb., respectively. Lot II received the same ration

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plus 20 gm. of chlortetracycline (Aureomycin [5]) per ton of feed. The pigs were housed in pens with concrete floors and had access to outdoor paved lots. Weights for feed efficiency and rate of gain were made weekly.

Four pigs of similar breeding, three gilts and one barrow, were randomly selected and fed the basal ration of Lot I until they reached a weight of 45 lb. They were then slaughtered and carcass data collected. This "Zero group" was not involved in the statistical analysis or compared to the experimental groups but was used to provide data on the composition of pigs near the start of the experiment.

As each pig reached its predetermined weight for removal from the experiment, a blood sample was collected from the vena cava and the plasma frozen until it could be analyzed for blood fat by the method of Allen (1938). This blood sample is called the "absorptive" sample. The pig was held off feed for 18–24 hours prior to slaughter, when a blood sample was again collected and treated as outlined above. This is called the "post-absorptive" sample.

At the time of slaughter the following weights were collected: live, scald, dressed, viscera (full and empty), small and large intestine, liver, heart, lungs, reproductive tract, stomach, spleen, pancreas, kidney, and leaf fat. After a 24–48 hour chill at 32–34° F., the carcass was removed from the chill room and split into two sides. The carcass and its various components were measured, cut and sampled.

To characterize the fat deposited, the following constants were determined on the back fat (which has been shown by Ellis and Hankins (1925) to be representative of the entire meat fat), leaf fat and ham fat: 1. The Hanus iodine number as outlined in A.O.A.C. (1950), to determine the degree of unsaturation, and 2. The percent of oleic, lineolic, and linolenic fatty acids and percent of saturated fatty acids by the method of Mitchell *et al.* (1943).

To secure a fat sample a 50 to 75 gm. sample of the adipose tissue was rendered slowly in a 100 ml. beaker until the fat-holding connective tissue was crisp and brown. The fat was then filtered through glass wool and stored in a stoppered test tube at 10 degrees F. until the fat constants and composition were determined.

The results of the growth data, daily rate of gain, and feed efficiency were analyzed by analysis of variance as outlined by Snedecor (1950).

[5] The crystalline Aureomycin was supplied by Lederle Laboratories.

Results and Discussion

Approximately six weeks after the start of the experiment four barrows and one gilt in Lot II reached a plateau in growth. These pigs gained from 1 to 3 lb. per week. The cornified layer of their skin was thickened and contained nuclei equal to parakeratosis. The granular layer of the skin was also thickened and, as with the cornified layers, was thrown up into folds. At this time a barrow in Lot II which had gained 2 lb. per week from the start of the experiment was also removed. After 12 weeks a barrow from Lot I also came down with parakeratosis and was removed from the experiment.

The loss of pigs due to parakeratosis severely altered the original design of the experiment. Table 1 shows the number of individuals in

TABLE 1. ORIGINAL AND FINAL DESIGN OF EXPERIMENT

	Weight group							
	85		125		165		205	
	Barrow	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow	Gilt
Lot I	3(3)[a]	3(3)	3(3)	3(3)	3(2)	3(3)	3(3)	3(3)
Lot II	3(1)	3(3)	3(3)	3(2)	3(2)	3(3)	3(1)	3(3)

[a] Final number of individuals in parentheses.

the original and final (in parentheses) design of the experiment. The loss of pigs from the experiment makes the drawing of valid conclusions from the small number of observations (one in some cases) quite hazardous. Since there were many missing data (seven), the correction for disproportionality using appropriate combinations of variables in multi-variate analyses would be cumbersome. Hence, it was decided to use the analysis of variance for unequal subclass numbers method of Snedecor. To rule out the possibility of sex differences inflating the error term, each sex was analyzed separately for differences due to treatment and weight.

One of the objectives of this experiment was to test the protein-sparing action of chlortetracycline. Hence, the protein levels were 2% below those usually recommended. At this level of protein (15%), which was comparable to the low level used by Burnside (1952), the supplementation of the ration with chlortetracycline gave an increase in the average daily gain of the barrows which was highly significant (1%). The weight at which the barrows were removed also had a highly significant effect. The treatment times weight interaction was also significant (5%) which would indicate that the treatment and

weight were not exerting their effect independently. In the gilts, treatment with chlortetracycline did not affect the average daily gains. The weight at which the gilts were removed had a significant effect on the daily gains, being higher in the 165- and 205-lb. weight groups. This interesting observation of barrows reacting favorably to chlortetracycline supplementation while the gilts did not raises an interesting point. Does castration, with its accompanying alteration of the hormone balance, make the animal respond differently to treatment with antibiotics?

The blood fat data reported in this study are divided into two groups —absorptive and post-absorptive. The absorptive blood fat levels in the 165–205 lb. groups were significantly higher than those of the 85-lb. group. This agrees with Allen's (1938) observation that heifers were consistently lower than lactating cows and that the blood from newborn calves did not possess enough fat to be detected. In this experiment the addition of chlortetracycline to the ration resulted in a lowering of the absorptive blood fat levels. These results are not in agreement with those of Perry *et al.* (1953) who reported higher levels of blood fat in response to chlortetracycline. However, these two works are not exactly comparable since the work at the Purdue Station was on serum while the work herein reported was on plasma.

The post-absorptive blood fat levels in the 125-lb. group were significantly higher than those of the 85-lb. group. The removal of the pigs from feed for 18 to 24 hours prior to slaughter had little effect on the blood fat levels. These results are contrary to those of Allen (1938) in cows, where severe underfeeding caused a sudden drop in blood fat within 24 hours. The blood fat levels of antibiotic treated groups were lower (not significantly) in all cases except in the 125-lb. group.

The average internal organ weight within each weight group and each treatment lot reveals no difference as a result of chlortetracycline supplementation. This is contrary to the results reported by Gordon (1952) that the small intestine of antibiotic fed chicks was markedly lighter in weight than that of the controls. The differences observed between weight groups parallel those of McMeekan (1940). Using the zero lot as the base the liver and pancreas increased approximately three times; whereas the stomach and intestines and kidney increased two times. Leaf fat, a later developing part, increased 22 times from the zero lot to the 205-lb. group.

A summary of the composition of the fat from the leaf, ham and back depots is presented in table 2. Only the iodine number (Hanus), percent

TABLE 2. SUMMARY OF FAT COMPOSITION DATA

	Leaf fat				Ham fat				Back fat			
	Iodine No.	Linoleic acid	Oleic acid	Unsaturated acids	Iodine No.	Linoleic acid	Oleic acid	Unsaturated acids	Iodine No.	Linoleic acid	Oleic acid	Unsaturated acids
		%	%	%		%	%	%		%	%	%
85-lb.												
Basal												
Barrows	58.9[a]	8.8	44.8	54.6	70.9[d]	9.9	55.5	66.6	70.7[e]	12.1	50.3	63.7
Gilts	60.4[b]	10.4	43.4[c]	54.8	70.8[d]	10.5	53.6	65.5	71.1	10.5	54.2[c]	66.0
Antibiotic												
Barrows	57.0	8.4	44.7	53.7	69.2	10.0	54.5	65.3	71.0	9.5	57.2	67.6
Gilts	59.1	6.5	50.6	57.7	71.9	11.9	52.1	65.3	68.7	13.4	45.0	59.9
125–lb.												
Basal												
Barrows	47.7	6.3	50.2	56.9	69.2	8.9	55.8	65.8	69.5	9.6	55.0	65.6
Gilts	57.5	6.8	48.6	56.0	69.9	10.3	54.1	65.4	69.6	10.6	52.9	64.6
Antibiotic												
Barrows	54.6	6.6	45.7	52.9	68.5	10.2	52.4	63.7	67.6	10.2	51.7	62.9
Gilts	57.6	5.4	55.7	57.0	70.0	7.4	59.6	68.2	69.6	10.8	52.8	64.6
165–lb.												
Basal												
Barrows	61.2	9.8	45.2	56.0	70.9	8.0	60.1	69.0	71.8	9.6	52.0	65.2
Gilts	54.9	6.3	46.0	53.1	66.6	7.5	56.5	64.8	66.1	7.1	57.1	64.9
Antibiotic												
Barrows	58.2	5.4	52.1	58.1	67.9	9.4	53.9	64.2	65.8	9.6	52.0	62.2
Gilts	55.5	5.8	48.7	55.0	68.5	8.2	56.6	65.8	66.3	9.1	52.7	62.7
205–lb.												
Basal												
Barrows	55.9	7.7	45.7	53.6	66.1	10.1	51.2	62.0	67.5	10.0	52.0	63.0
Gilts	56.5	5.7	49.5	55.8	65.5	7.6	55.0	63.5	65.1	8.0	54.7	63.3
Antibiotic												
Barrows	53.4	6.4	45.3	52.1	68.2	7.7	57.7	66.3	63.5	7.6	51.8	60.6
Gilts	55.3	6.0	48.1	54.5	65.6	9.0	52.7	62.5	64.9	9.5	50.2	60.7

[a] Difference due to treatment of barrows approaches significance at 5%.
[b] Difference due to weight significant at 5%.
[c] Difference due to treatment of gilts significant at 5%.
[d] Difference due to weight at which removed significant at 5%.
[e] Difference due to treatment of barrows significant at 1%.

linoleic, percent oleic, and percent unsaturated fatty acids are presented.

Differences due to treatment were not noted in the iodine number of the ham fat from either barrows or gilts. The iodine number of the leaf and back fat from barrows was lower in the antibiotic supplemented lots. The difference in iodine number of leaf fat of barrows approached significance at the 5% level while the iodine number of the back fat from barrows was highly significantly lower due to treatment. It is interesting to note that here again the gilts have not responded to treatment in the same order of magnitude as the males. This was pointed out in the average daily gains discussion where it was shown that the treated barrows gained at a greater rate than did the gilts. Callow (1950) has shown that where the rate of fat deposition is low the iodine number is the highest and that where fat deposition is fast the iodine number is the lowest. If the treated barrows on this experiment were depositing fat at a greater rate, it is logical to expect the fat to be more highly saturated and have a lower iodine number. Examination of table 2 also shows that the iodine number of the leaf fat is considerably lower than that of the ham or back fat. These results agree with those of Ellis and Hankins (1925) in their studies on soft pork.

There was no difference in the percentage of either linoleic or total unsaturated fatty acids of the leaf, ham, or back fat due to treatment or weight at which removed from the experiment. A great deal of variation in fatty acid composition was found within weight groups and treatment lots. The percent of oleic acid in the leaf fat from gilts was significantly higher due to antibiotic supplementation whereas in the back fat the percent of oleic acid was significantly lowered as a result of chlortetracycline in the ration.

Table 3 presents a summary of the results of chemical analysis of the carcass, ham, and shoulder composites. The effect of treatment with chlortetracycline was not significant. These results agree with those of Hanson *et al.* (1954). The treatment-weight interaction was not significant. The percent water of carcass, ham and shoulder composite decreased as the weight of the carcass increased. The decrease in percent water of the carcasses from barrows was significant in the carcass composite and highly significant in the shoulder and ham composites. In the gilts the decrease in percent water was highly significant for carcass, shoulder and ham composites. The fat increased with increasing weight and was either significant, or highly significant as was the percent water. Most of the difference in composition appears to be due to changes in moisture and fat with the percent protein remaining more

TABLE 3. SUMMARY OF CHEMICAL COMPOSITION OF CARCASS, HAM, AND SHOULDER COMPOSITES

Weight groups	Carcass composite			Shoulder composite			Ham composite		
	Water	Fat	Protein	Water	Fat	Protein	Water	Fat	Protein
	%	%	%	%	%	%	%	%	%
85-lb.									
Basal									
Barrows	52.5[a]	34.5[a]	10.6	56.2[c]	31.2[c]	12.6[c]	65.9[c]	20.3[c]	14.7
Gilts	51.7[b]	35.9[b]	12.4[b]	55.2[b]	32.4[b]	11.8	65.2[b]	22.6[b]	12.7
Antibiotic									
Barrows	48.8	39.3	11.7	53.0	32.5	11.9	57.9	26.7	15.0
Gilts	55.6	30.6	14.2	58.3	28.1	13.3	68.7	17.	14.8
125-lb.									
Basal									
Barrows	45.3	43.9	10.5	51.9	36.7	11.4	55.0	32.8	13.4
Gilts	45.5	43.5	10.9	52.7	35.1	11.5	54.4	32.7	13.3
Antibiotic									
Barrows	48.3	39.3	12.4	51.7	36.7	12.0	58.8	26.8	14.4
Gilts	49.6	38.6	11.6	55.9	31.9	13.0	56.8	28.2	14.4
165-lb.									
Basal									
Barrows	48.2	40.0	12.8	49.4	38.4	11.2	55.3	28.7	14.6
Gilts	45.0	44.3	11.0	48.0	40.5	11.3	53.9	33.5	13.4
Antibiotic									
Barrows	47.2	41.0	11.8	49.0	38.0	11.8	54.2	33.9	11.1
Gilts	44.5	44.6	11.1	48.1	40.7	11.2	54.8	32.9	11.8
205-lb.									
Basal									
Barrows	42.4	47.9	10.1	43.3	44.7	10.3	53.1	34.8	13.1
Gilts	42.7	46.4	11.1	47.7	41.8	10.9	50.8	37.2	13.3
Antibiotic									
Barrows	43.0	47.4	10.8	44.2	47.7	9.4	56.1	32.6	14.1
Gilts	41.4	47.8	11.0	44.2	44.6	10.6	52.1	35.6	12.4

[a] Difference due to weight barrows removed significant at 5%.
[b] Difference due to weight gilts removed significant at 1%.
[c] Difference due to weight barrows removed significant at 1%.

nearly constant. Two exceptions are the decline in percent protein of the gilts' carcass composite and the barrows' shoulder composite.

Table 4 is a summary of the carcass measurements taken and shows that of the carcass measurements (dressing percentage, length, loin eye area, percent primal cuts and percent lean cuts) no significant differences were observed as a result of antibiotic supplementation. However, the means indicate that treatment produces a trend toward increased carcass fatness, especially in the heavier groups. These results are similar to those obtained by Wilson *et al.* (1953). They do not agree with the results of Brown *et al.* (1951) and Wallace *et al.* (1954) who reported higher dressing percentages in animals fed antibiotics. Table 4 shows that supplementation of the ration with chlortetracycline significantly increased the average back fat thickness of barrows. This effect can also be seen in the means for lean cut yield and the carcass composite data. The chlortetracycline did not significantly affect the average back fat thickness of the gilts. In order to investigate the effect of chlortetracycline on the growth-gradient theory expressed by McMeekan (1940), i.e. the early anterior development compared to the later posterior development, the average back fat thickness over the first rib (early developing) and last lumbar vertebra (later developing) were analyzed separately. In neither barrows or gilts were significant differences detected as a result of chlortetracycline treatment. In short, the significant increase in back fat thickness of the barrows was not the result of overdevelopment of the fat depots in the shoulder or loin regions. Likewise in the gilts no region was found to exert an undue effect on the average back fat thickness. It is generally agreed that over-fat hogs are heavier in the shoulders and that this excess weight results from large deposits of intermuscular and subcutaneous fat. Chlortetracycline did not appear to affect the fat deposition pattern in the pigs on this study.

The influence of antibiotics on specific gravity of the carcass was not clear-cut and not significant. The specific gravity of the carcass was influenced by the weight at which the animals were removed, being the greatest for the pigs in the 85 and 125-lb. weight groups and least in the 165 and 205-lb. groups.

The effect of treatment upon the chemical composition of the various carcass components (loin eye, ham eye, Boston butt lean, and ham lean) was small and not statistically significant for any of the tissues studied.

[a] Difference due to weight gain removed significant at 1%.

TABLE 4. SUMMARY OF CARCASS PHYSICAL MEASUREMENTS

Weight groups	Live weight	Slaughter weight	Dressing	Length	Backfat thickness cm.			Loin eye area	Primal cuts	Lean cuts	Specific gravity
					First rib	Last lumbar	Av.				
	lb.	lb.	%	cm.				cm.	%	%	
Zero	45	41.8	62.4	46.4	1.80	1.10	1.30	11.0	73.8	59.7	1.057
85-lb.											
Basal											
Barrows	85.0	80.3	66.8	59.1	2.83	1.93	2.07[a]	15.7	71.8	55.2	1.050
Gilts	85.0	79.0	68.4	58.4	2.75	1.97	2.04	16.2	72.9	55.7	1.044
Antibiotic											
Barrows	85.0	81.0	69.1	58.4	3.14	1.90	2.40	18.2	72.0	55.7	1.045
Gilts	85.0	79.7	68.7	57.9	2.92	1.81	2.06	17.9	75.7	60.5	1.050
125-lb.											
Basal											
Barrows	125	118.3	71.6	65.8	3.55	2.63	2.83	21.6	70.1	53.2	1.040
Gilts	125	118.0	72.3	66.7	3.87	3.22	3.08	22.4	70.8	52.0	1.038
Antibiotic											
Barrows	125	118.0	70.3	63.4	3.76	2.74	2.92	22.2	72.8	54.5	1.040
Gilts	125	115.0	71.3	66.0	3.44	2.76	2.66	22.3	71.5	53.2	1.046
165-lb.											
Basal											
Barrows	165	156.5	71.9	71.4	3.72	2.36	2.84	29.8	72.3	54.0	1.035
Gilts	165	154.3	73.5	69.6	4.12	3.74	3.58	26.1	70.3	51.8	1.037
Antibiotic											
Barrows	165	159.0	71.7	69.4	4.12	3.46	3.52	26.2	69.0	50.5	1.038
Gilts	165	158.3	73.5	70.2	4.55	3.57	3.60	29.3	67.3	50.1	1.035
205-lb.											
Basal											
Barrows	205	195.0	74.2	73.4	5.11	3.51	3.92	30.6	68.8	50.7	1.027
Gilts	205	195.3	74.5	75.5	4.96	4.26	4.20	32.9	68.7	50.1	1.032
Antibiotic											
Barrows	205	194.0	76.3	73.6	4.90	3.84	4.14	36.0	68.4	49.7	1.028
Gilts	205	198.3	75.6	74.5	5.18	4.41	4.26	31.5	66.9	48.7	1.029

[a] Difference due to treatment of barrows significant at 5%.

Summary

Data have been obtained on the effect of chlortetracycline (crystalline Aureomycin) supplementation in practical rations of pigs from weaning to 85, 125, 165, and 205-lb. at which time they were slaughtered and the blood and carcass data collected.

At a 15% protein level the supplementation of the ration with chlortetracycline gave an increase in the average daily gain of the barrows which was highly significant (1%). The weight at which the barrows were removed also had a highly significant effect on average daily gains. In the gilts, treatment with chlortetracycline did not affect the average daily gains. The weight at which the gilts were removed had a significant (5%) effect upon the average daily gains.

The blood fat levels for the chlortetracycline supplemented lots were lower (not significantly) than the blood fat levels of the controls. The absorptive blood fat levels of the 165 and 205-lb. groups were significantly higher than the levels of the 85-lb. groups.

The iodine number of the leaf and back fat from barrows was lower (near 5% and 1%, respectively) due to chlortetracycline supplementation.

There was no significant difference in percentage of moisture, ether extract, or protein of the carcass, shoulder or ham composites and all physical carcass measurements except back fat thickness as a result of chlortetracycline supplementation.

The average back fat thickness of the males was significantly (5%) increased as a result of chlortetracycline supplementation. This finding is in agreement with the trend toward greater carcass fatness as expressed in other physical and chemical measurements.

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SPECIFIC GRAVITY AND CHEMICAL COMPOSITION OF THE UNTRIMMED HAM AS RELATED TO LEANNESS OF PORK CARCASSES [1]

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THE surplus lard problem has stimulated production of leaner, meatier hogs. The resultant evaluation and certification programs have increased the need for simple, accurate methods of estimating the desirable traits of swine. A simple tool for evaluation of the carcass must not only measure cutting percentages, but must provide an estimate of muscling.

Warner *et al.* (1934) postulated that chemical analysis of the entire carcass is the most accurate measure of leanness or fatness, but this method is tedious and time consuming. Average backfat thickness has been generally accepted as the simplest measure of leanness, but Brown *et al.* (1951) found that specific gravity of the carcass was more highly related to cut-out and chemical analysis than backfat thickness. Whiteman *et al.* (1953) verified these results, and in a subsequent study found a high relationship between ham and carcass specific gravities. In studying the relationship between specific gravity of untrimmed pork cuts and specific gravity of the carcass, Pearson *et al.* (1956) reported the ham to be more closely associated with the carcass than any other cut studied. Results verified the earlier work showing that specific gravity of the ham was more closely related to cut-out than backfat thickness. The present study was undertaken to ascertain the reliability of ham specific gravity as an index of leanness by testing its relation to cut-out, chemical analysis and other commonly used indicators of leanness.

Materials and Methods

Experimental Animals and Cutting Procedures

Thirty-six hogs which came from various feeding experiments were used in this study. No attempt was made to segregate them into groups

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[2] From a portion of a thesis submitted by J. F. Price to the College of Agriculture, Michigan State University, in partial fulfillment of the requirements for the M.S. degree, 1956.
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according to breed or nutritional background. There were 15 Durocs, 7 Chester Whites, 12 Hampshires and 2 Yorkshire-Chester crossbreds. The hogs were handled, slaughtered, cut and measured in the same manner as reported by Pearson *et al.* (1956).

Specific Gravity Determinations

Specific gravity was determined by the under water weighing technique described by Brown *et al.* (1951) with variations as discussed by Pearson *et al.* (1956). Specific gravity determinations were made on the entire carcass and the untrimmed right ham.

Chemical Analysis

The entire right ham was boned, skinned, and ground five times through a 3/32 inch grinding head for sampling. This method had been proven satisfactory by Benne *et al.* (1956). Approximately 60–72 hours after sampling, analysis was made for moisture, ether extract and protein according to procedures outlined by Benne *et al.* (1956).

Results and Discussion

The specific gravity of the untrimmed right ham was consistently greater than that of the carcass as shown in table 1. Table 1 also contains the means, standard deviations and standard errors for the various measurements.

In this study, the correlation coefficients (table 2) relating carcass specific gravity and the various cut-out percentages follow the same general trend as those obtained by Pearson *et al.* (1956). The specific gravity of the carcass showed a higher relationship with the specific gravity of the untrimmed ham than to any other measure, having a correlation coefficient of .86. This indicated that 74% of the variation in carcass specific gravity was associated with a similar variation in ham specific gravity. However, slightly higher correlation coefficients were obtained between carcass specific gravity and each individual chemical component, each cut-out percentage, backfat thickness, live probe, and loin lean areas than between ham specific gravity and the same values. Carcass specific gravity was not significantly related to carcass length or dressing percentage.

Specific gravity of either the untrimmed ham or entire carcass showed a closer relationship to cut-out percentages than lean area of the loin at the last rib or carcass length. Loin lean area at the tenth rib and

ham specific gravity showed a very similar relationship to lean cuts. Both specific gravity values were significantly related to each chemical component at the 1% level. Correlation coefficients obtained relating specific gravity and each chemical component were higher than those obtained with either loin lean area, carcass length, live probe, or backfat

TABLE 1. MEANS, STANDARD DEVIATIONS AND STANDARD ERRORS FOR VARIOUS MEASUREMENTS

	Mean	Standard deviation	Standard error
Live weight—shrunk, lb.[a]	199.2	18.32	3.05
Specific gravity—carcass	1.027	0.0059	0.0010
Specific gravity—right ham	1.042	0.0068	0.0011
Ether extract, % in ham	37.38	3.61	0.60
Water, % in ham	48.38	2.74	0.46
Crude protein, % in ham	14.05	0.88	0.15
Lean cuts—live basis, %	34.95	2.05	0.34
Lean cuts—carcass basis, %	46.70	2.83	0.47
Primal cuts—live basis, %	46.22	2.08	0.35
Primal cuts—carcass basis, %	61.75	2.90	0.48
Lean cuts minus fat trim, %[b]	21.09	5.35	0.89
Fat trimmings, %[b]	25.60	2.81	0.47
Backfat thickness, in.[c]	1.78	0.20	0.03
Live probe, in.[d]	1.73	0.23	0.04
Carcass length, in.	28.32	0.86	0.14
Area of lean in loin at 10th rib, sq. in.	3.64	0.51	0.09
Area of lean in loin at the last rib, sq. in.	4.03	0.58	0.10
Dressing percentage, %[e]	74.87	1.36	0.23

[a] 24-hour shrunk weight.
[b] Computed on carcass basis-cold weight.
[c] Average of 4 measurements.
[d] Average of 6 probes.
[e] Dressing percentage $= \frac{\text{cold carcass weight}}{\text{shrunk live weight}} \times 100$.

thickness related to the same chemical components. This indicated that either carcass or ham specific gravity was a better measure of percentage ether extract, moisture, or protein than any other measure tested. However, highly significant correlation coefficients were obtained between each chemical component and loin lean area at the tenth rib, live probe, and backfat thickness as shown in table 2. This indicated that loin lean area at the tenth rib, live probe, and backfat thickness were relatively good indicators of chemical composition of the untrimmed ham.

Negative, highly significant correlation coefficients were obtained between live probe and the following cut-out percentages: lean cuts—live basis, lean cuts—carcass basis, primal cuts—both bases, and lean

TABLE 2. CORRELATION COEFFICIENTS FOR VARIOUS CARCASS MEASUREMENTS, SPECIFIC GRAVITY AND CHEMICAL COMPOSITION

	Sp. gravity carcass	Sp. gravity right ham	Area lean 10th rib	Area lean last rib	Carcass length	Live probe	Backfat thickness	Slaughter weight
Sp. gravity–carcass		.86**	.61**	.52**	.32	—.61**	—.59**	—.21
Sp. gravity–rt. ham	.86**		.60**	.48**	.34*	—.47**	—.44**	—.12
Ether extract in ham	—.85**	—.74**	—.66**	—.48**	—.21	.67**	.61**	
Water in ham	.83**	.70**	.64**	.46**	.22	—.67**	—.69**	
Protein in ham	.82**	.76**	.59**	.38*	.09	—.60**	—.63**	
Lean cuts–live basis	.67**	.52**	.57**	.40*	.15	—.78**	—.67**	
Lean cuts–carcass	.65**	.47**	.50**	.35*	.02	—.83**	—.72**	
Primal cuts–live	.58**	.57**	.46**	.34*	.23	—.73**	—.60**	
Primal cuts–carcass	.59**	.50**	.37*	.28	.05	—.79**	—.66**	
Lean cuts minus fat trim	.67**	.52**	.51**	.33*	.10	—.84**	—.73**	
Fat trim	—.63**	—.52**	—.47**	—.27	—.17	.77**	.67**	
Backfat thickness	—.59**	—.44**	—.18	—.10	—.09	.87**		.57**
Live probe	—.61**	—.47**	—.21	—.08	—.03		.87**	.63**
Carcass length	.32	.34*	.33*	.30		—.03	—.09	.54**
Area lean–10th rib	.61**	.60**		.82**	.33*	—.21	—.18	.16
Area lean–last rib	.52**	.48**	.82**		.30	—.08	—.10	.42**
Dressing percent	.00	.12	.20	.09				.27
Slaughter weight	—.21	—.12	.16	.42**	.54**	.63**	.57**	

* Significant at 5% level.
** Significant at 1% level.

cuts minus fat trim. The same was true with backfat thickness and these cut-out values, however, live probe consistently showed a closer relationship with cut-out percentages than backfat thickness. Both live probe and backfat thickness were more highly correlated with cut-out than either specific gravity value.

Although the two loin lean area measurements were closely related (.82), the lean area of the loin measured at the tenth rib showed closer relationships with specific gravity values and cut-out values than the loin lean area at the last rib. This indicated that the loin area at the tenth rib was a more reliable measure of leanness than the loin lean area at the last rib.

TABLE 3. MULTILINEAR CORRELATIONS FOR CERTAIN MEASUREMENTS OF LEANNESS

	Live probe and length	Backfat and length	Ether extract, water and protein
Specific gravity, carcass			.88**
Specific gravity, right ham			.87**
Lean cuts, live basis, %	.79**	.70**	
Lean cuts, carcass basis, %	.83**	.72**	
Primal cuts, live basis, %	.76**	.63**	
Primal cuts, carcass basis, %	.80**	.66**	
Lean cuts minus fat trim, %	.84**	.73**	
Fat trimmings, %	.78**	.68**	

** Significant at 1% level.

The lean area of the loin measured at either the tenth or last rib showed a closer relationship to specific gravity of the ham or carcass than to live probe or backfat thickness, indicating that either specific gravity value was a more reliable measure of actual muscling than fat thickness. This conclusion was substantiated by the larger correlation coefficients between chemical analysis and specific gravity values than between chemical composition and fat thickness.

Carcass length was not significantly related to any other measure of leanness except specific gravity of the ham and loin lean area at the tenth rib. The relationships of length and specific gravity and loin lean area were significant only at the five percent level. Also, dressing percentage was not significantly related to either specific gravity or loin lean area. Multilinear correlation coefficients (table 3) of specific gravity with ether extract, moisture and protein content of the ham increased the association over that with any single chemical component.

Although chemical analysis was made on a single ham, the specific gravity of the entire carcass showed equally as high a multilinear relationship with chemical composition as did ham specific gravity (table 3). A multiple correlation coefficient of .88 indicated that 77% of the variation in chemical composition of the ham was accompanied by corresponding variation in carcass specific gravity. Likewise, 75% of the variation in ham specific gravity was accounted for by changes in chemical composition.

Also shown in table 3, the combined measure of live probe and carcass length was associated closely with carcass cut-out percentages. All multilinear correlation coefficients were significant at the 1% level.

TABLE 4. PARTIAL CORRELATION COEFFICIENTS FOR SPECIFIC GRAVITY WITH THE EFFECTS OF SLAUGHTER WEIGHT REMOVED

	Specific gravity carcass	Specific gravity ham
Backfat thickness	—.58	—.46
Live probe	—.63	—.51
Carcass length	.52	.42
Area-lean–10th rib	.67	.63
Area lean–last rib	.68	.59
Dressing percentage	.06	.16

This was also the case with backfat thickness and carcass length as a combined estimate of carcass composition. However, the combined estimates (table 3) gave only slight improvement over the use of backfat thickness or live probe alone (table 2) as an estimate of cut-out. The extra work and computations necessary to obtain the multilinear correlation coefficients and combined estimates offset the closer relationship. Thus, the inclusion of carcass length gave little information of value. These conclusions were substantiated by the low relationship of carcass length and any single cut-out percentage (table 2).

Partial correlation coefficients (Snedecor, 1946) were calculated to remove the influence of slaughter weight variation on a number of carcass traits. The similarity of the correlation coefficients, which were uncorrected for weight (table 2), with those in which the effect of weight was removed reveals that weight variation had little influence on the traits studied (table 4).

Lean cuts (live basis) showed closer relationships with carcass spe-

cific gravity, both loin lean areas, live probe, and backfat thickness than primal cuts, live basis (table 2). Also, lean cuts on the carcass basis were more closely associated with the above mentioned items than primal cuts-carcass basis. This indicated that specific gravity of the carcass, lean area of the loin, live probe, and backfat thickness more closely predicted percentage lean cuts than primal cuts. As a measure of carcass composition, the computed value, lean cuts minus fat trim, was equally as predictable as lean cuts, and may be used as another reliable tool in evaluating pork carcasses.

Summary

The specific gravity of the untrimmed right ham was found to be closely associated with the specific gravity of the entire carcass with a correlation coefficient of .86. However, cut-out percentages, chemical composition of the ham, loin lean areas, and fat thickness measures were not as closely predicted by ham specific gravity as by carcass specific gravity. The correlation coefficients obtained between ham specific gravity and the above mentioned items were all highly significant.

In this study, contrary to previous work, carcass cut-out was more closely associated with live probe and backfat thickness than with specific gravity of the ham. However, specific gravity of the untrimmed ham more closely predicted its chemical composition than lean areas of the loin, carcass length, live probe, or backfat thickness.

Results indicated that specific gravity of the ham or carcass was a more reliable indicator of muscling, or actual meatiness, than live probe or backfat thickness. This conclusion was based on a higher correlation of specific gravity and loin lean areas than between fat thickness and lean areas. Added proof was drawn from the closer relation of specific gravity and chemical components than of fat thickness measures and chemical composition.

Carcass length showed no significant relationship with cut-out, chemical composition, or exterior fat thickness. Carcass length combined with backfat thickness or live probe gave little advantage over the use of backfat or live probe alone. Dressing percentage was not significantly associated with specific gravity or loin lean area. In this study the lean area of the loin measured at the tenth rib more closely predicted cut-out than the same area measured at the last rib.

In general, lean cut-out was more closely associated with other measures of leanness than primal cut-out.

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THE EFFECTS OF CORN TREATED WITH FUNGICIDES UPON THE PERFORMANCE OF FATTENING STEERS

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SEED corn entering into commercial trade channels is generally treated with fungicides to protect the seed and seedling during germination and emergence. Two of the compounds widely used are known commercially as Arasan and Orthocide. The active ingredient in Arasan is tetramethyl thiuram disulphide. The Arasan preparation used in this trial was a wettable powder containing 50% of the active ingredient. The active ingredient in Orthocide is captan, the generic name given for N-trichloromethylmercapto-4-cyclohexene-1,2-dicarboximide. The Orthocide preparation used in this study was a wettable powder containing 75% captan.

The amount of seed corn treated annually is normally in excess of the amount needed for planting and that not planted may eventually be used in beef cattle rations. Excess treated seed corn is normally processed to remove approximately half of the original fungicide. However, the possibility remains that the residual fungicide may have toxic effects upon cattle to which it is fed.

The question of toxicity led to an investigation of the effect of Arasan and Orthocide on the feed consumption and gain of fattening steers. The toxicity of dithiocarbamates, including tetramethyl thiuram disulphide, was studied by Brieger and Hodes (1948) who found the LD 50 of the latter compound to be 0.21 gm. per kg. for rabbits. A release (1952) by the committee on pest control states that Orthocide used as a wettable powder has a low order of toxicity for warm blooded animals. An LD 50 of more than 15 gm. per kg. is given for rats. Ackerson and Mussehl (1954) used corn treated with Arasan and Orthocide in chick rations. These workers reported that the ration containing Arasan caused a depression of growth rate which persisted until the Arasan was withdrawn after 28 days. Subsequently, the chicks gained at a satisfactory rate. The chicks that received the diet containing Orthocide showed a slight tendency toward a slower growth during the early part of the

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trial, but at 28 days had made the same total gains as the control chicks. Meade and Warner (1954) fed growing fattening swine complete mixed rations containing corn treated with different amounts of the fungicides. No gross pathological manifestations were observed which could be attributed to fungicide treatments. However, the use of rations containing corn treated with twice the amount of fungicide recommended by the manufacturer seriously reduced palatability of the rations, average daily gains and the efficiency of feed utilization.

The rumen microorganisms that are vital to the nutritional well-being of steers are known to be sensitive to many compounds. Since the active ingredients in Arasan and Orthocide are fungicides, it was felt that they might affect the rumen microorganisms and in turn the performance of fattening steers. This experiment was conducted to obtain information on the toxicity of these materials and their effects on the feed consumption and gain of such animals.

Experimental Procedure

Thirty-three Hereford steers approximately 18 months of age were individually fed in this experiment. Seven treatments were used: control, 3 levels of Arasan and 3 levels of Orthocide. The steers were randomly assigned to the 7 treatments. Four steers were fed the control ration, 15 steers were fed the rations containing Arasan, and 14 steers were fed the rations containing Orthocide. Each steer was assigned to a self-feeder and was given free access to the feed twice daily, once for a 2-hour period during the morning and a second time for a 2-hour period during the evening. At the conclusion of the 140-day feeding period the steers were slaughtered. Dressing percentages and carcass grades were obtained. No attempt was made to determine tissue storage of these two fungicides.

The three levels of Arasan used in this experiment were corn treated with: (1) half the treatment level recommended by the company producing the fungicide, (2) the recommended treatment level, and (3) twice the recommended treatment level. These three treatment levels were designated as ½X Arasan, 1X Arasan and 2X Arasan, respectively. The same procedure was followed with Orthocide. The fungicides were applied as a slurry. The amounts of fungicides applied to the corn are shown in table 1.

The corn was coarsely cracked with a hammermill and mixed with chopped alfalfa hay. The complete rations contained 67% corn and 33% chopped alfalfa hay.

Results and Discussion

The results are summarized in table 2. All of the steers appeared healthy throughout the 140-day feeding period and did not appear abnormal in any way. The droppings of the steers fed the Arasan treated corn appeared normal in all respects except that they were almost black in color. The steers did not scour or exhibit any other digestive disturbances.

The steers fed the rations that contained the corn treated with 1X level of Orthocide made the largest average daily gains, and the steers

TABLE 1. FUNGICIDE APPLICATIONS TO THE CORN FED

	Per bushel		Per 100 lb.	
Treatment	Ounces	Grams	Ounces	Grams
Control	0	0	0	0
Arasan				
½×level	0.33	9.5	0.59	16.7
1×level	0.66	18.9	1.18	33.5
2×level	1.32	37.9	2.36	67.0
Orthocide				
½×level	0.33	9.5	0.59	16.7
1×level	0.66	18.9	1.18	33.5
2×level	1.32	37.9	2.36	67.0

fed the corn treated with the 2X level of Orthocide made the second largest average daily gains. The smallest average daily gains were made by the steers fed the ration containing corn treated with the 2X level of Arasan. The steers fed the control ration, and the rations containing corn treated with ½X level of Arasan, 1X level of Arasan, and ½X level of Orthocide all made approximately the same average daily gains.

When average daily gains per head for all treatments were subjected to an analysis of variance the differences between treatments were not significant. It is of interest to note, however, that the difference in average daily gains between the steers fed the control ration and the steers fed the ration containing corn treated with the 1X level of Orthocide amounted to 0.42 lb. per head daily in favor of the steers fed the treated corn.

The average daily gains made by the steers fed the rations containing corn treated with Arasan decreased as the level of Arasan in the rations increased. Since feed consumption also decreased as the the levels of

TABLE 2. PERFORMANCE DATA OF STEERS FED RATIONS CONTAINING ARASAN AND ORTHOCIDE

Steer no.	Initial weight	Final weight	Total gain	Average daily gain	Total feed	Average daily feed	Feed/ 100 lb. gain	Dressing %	Carcass grade[a]	Grams/ day of fungicide
	lb.	lb.	lb.	lb.	lb.	lb.	lb.			
Control										
148	717	1058	341	2.44	3399	24.3	996.8	57.0	LG	0
161	802	1017	215	1.54	2994	21.4	1392.6	61.6	HG	0
308	737	1028	291	2.08	3440	24.6	1182.1	57.4	LC	0
427	885	1142	257	1.84	2536	18.1	986.8	57.9	AG	0
Average	785.2	1061.2	276.0	1.98	3092	22.1	1120.3	58.5		
½X Arasan										
120	750	1037	287	2.05	2940	21.0	1024.4	57.7	LG	2.35
137	807	1103	296	2.11	3029	21.6	1023.3	59.3	LC	2.42
304	677	953	276	1.97	2513	18.0	910.5	57.0	HC	2.01
336	763	982	219	1.56	2769	19.8	1264.4	57.0	LC	2.21
470	885	1217	332	2.37	3050	21.8	918.7	59.7	LC	2.44
Average	776.4	1058.4	282.0	2.01	2860	20.4	1014.2	58.1		2.28
1X Arasan										
135	720	1050	330	2.36	3052	21.8	924.8	59.3	HG	4.89
144	800	1117	317	2.26	2640	18.8	832.8	58.9	HG	4.23
218	745	987	242	1.73	2664	19.0	1087.4	55.7	HC	4.27
227	807	1017	210	1.50	2435	17.4	1159.5	59.3	AG	3.91
396	792	1007	215	1.54	2371	16.9	1102.8	57.3	AG	3.80
Average	772.8	1035.6	262.8	1.88	2632	18.7	1001.5	58.1		4.22
2X Arasan										
66	715	1015	300	2.14	2487	17.8	829.0	57.4	AG	7.97
145	723	897	174	1.24	1807	12.9	1038.5	57.4	AG	5.43
209	913	1093	180	1.28	2238	16.0	1243.3	59.5	HG	7.18
319	788	1070	282	2.01	2332	16.6	826.9	55.7	LG	7.48
459	770	1060	290	2.07	2762	19.7	952.4	58.0	AG	8.86
Average	781.8	1027.0	245.2	1.75	2325	16.6	948.3	57.6		7.46
½X Orthocide										
76	832	1152	320	2.28	3227	23.0	1008.4	58.4	LG	2.58
102	757	1002	245	1.75	2487	17.8	1015.1	56.6	LC	1.99
150	857	1093	236	1.68	2685	19.2	1137.7	58.1	LG	2.14
284	672	938	266	1.90	3015	21.5	1133.4	58.7	LG	2.41
Average	779.5	1046.2	266.7	1.90	2854	20.4	1069.7	58.0		2.28
1X Orthocide										
47	820	1148	328	2.34	3482	24.9	1061.6	60.7	AG	5.58
139	743	1033	290	2.07	2851	20.4	983.1	57.8	LG	4.57
314	712	1083	371	2.65	2827	20.2	762.0	58.5	HG	4.53
335	842	1143	301	2.15	3292	23.5	1093.7	59.8	LC	5.28
493	775	1158	383	2.74	3126	22.3	816.2	60.4	LC	5.01
Average	778.4	1113.0	334.6	2.39	3116	22.3	931.3	59.4		4.99
2X Orthocide										
50	720	1003	283	2.02	2358	16.8	833.2	55.9	HC	7.56
149	752	1007	255	1.82	2536	18.1	994.5	54.6	AG	8.13
489	785	1098	313	2.25	2743	19.6	876.4	61.3	AC	8.79
448	798	1113	315	2.25	3307	23.6	1049.8	58.0	HG	10.60
422	852	1158	306	2.18	2887	20.6	943.5	58.8	AC	9.26
Average	781.4	1075.8	294.4	2.10	2766	19.7	939.5	57.7		8.86

[a] Carcass grades: HC=High Choice, AC=Average Choice, LC=Low Choice, HG=High Good, AG=Average Good, LG=Low Good.

Arasan in the rations increased, the decreased gain was probably due to decreased feed consumption, rather than to toxic effects of the Arasan. When feed consumption for all treatments was analyzed statistically the differences between rations were significant. However, the significant differences in feed consumption did not result in a significant difference in gains. This is probably associated with the limited number of animals used in this trial.

Since the cumulative effects of the rations are generally of interest, the average total gains for each of the five 28-day periods are shown in table 3.

TABLE 3. AVERAGE TOTAL GAIN PER STEER BY 28-DAY PERIODS

	1st 28-day	2nd 28-day	3rd 28-day	4th 28-day	5th 28-day	Total gain
Controls	56.0	116.2	75.0	15.0	13.8	276.0
½×Arasan	50.6	117.0	51.0	49.0	14.4	282.0
1×Arasan	43.2	110.0	55.0	42.0	12.6	262.8
2×Arasan	23.2	104.0	68.0	24.0	26.0	245.5
½×Orthocide	56.7	115.0	31.2	48.8	15.0	266.7
1×Orthocide	90.6	115.0	67.0	22.0	41.0	334.6
2×Orthocide	68.6	121.0	29.0	49.0	27.0	294.6

The steers fed the ration containing the corn treated with the ½X level of Arasan consumed 20.5 lb. of feed per head daily and gained 2.01 lb., while the steers fed the control ration consumed 22.1 lb. of feed per head daily and gained 1.97 lb. The ½X level of Arasan treated corn resulted in an average daily consumption of approximately 250 mg. of Arasan per 100 lb. of liveweight which furnished 125 mg. of tetramethyl thiuram disulphide per 100 lb. of liveweight. Based on these results it is suggested that Arasan treated corn be processed to remove part of the original fungicide or mixed with non-treated grains so that the daily consumption of Arasan will not furnish more than 125 mg. of tetramethyl thiuram disulphide per 100 lb. of liveweight. Arasan fed at higher levels in this investigation depressed feed consumption and gains but did not appear to be toxic to the steers. No gross pathological manifestations were observed which could be attributed to Arasan. The steers used in this trial were yearlings. Younger cattle might react differently.

In the rations fed in this trial the 1X level of Orthocide treated corn resulted in an average daily consumption of approximately 525 mg.

of Orthocide per 100 lb. of liveweight which furnished 395 mg. of captan per 100 lb. of liveweight. The 2X level of Orthocide treated corn resulted in an average daily consumption of approximately 965 mg. of Orthocide per 100 lb. of liveweight which furnished 725 mg. of captan per 100 lb. of liveweight. The rations containing corn treated with the 1X and 2X levels of Orthocide appeared to improve the rate of gain and the efficiency of feed utilization of the steers to which it was fed, while the ration containing corn treated with the ½X level of Orthocide did not. However, the steers fed the ration containing corn treated with the 2X level of Orthocide consumed less feed than the steers fed either the control ration or the rations containing corn treated with the ½X and 1X levels of Orthocide.

The average feed consumption per 100 lb. of gain was less for the steers fed rations containing corn treated with Arasan or Orthocide than for the steers fed the control ration. These results suggest that the fungicides may have affected either the absorption or the utilization of the nutrients in the rations. These points were not investigated and this trial was not extensive enough to justify such a conclusion.

Since the steers were of similar conformation, quality and condition at the beginning of the trial it is logical to assume that the degree of fatness at the time of slaughter was largely a manifestation of ration effects. The differences in carcass grades and dressing percentages between treatments were not great. However, the average dressing percent of the steers that received the corn treated with the 2X level of Arasan was slightly lower than the average dressing percent of the steers that received the control ration. In general, the carcass grades were rather uniform between treatments.

Summary

Thirty-three yearling Hereford steers were individually fed to study the toxic effects of the seed protectants Arasan and Orthocide in fattening rations. Seven treatments were used: control, 3 levels of Arsan and 3 levels of Orthocide.

No toxic effects were noted during the 140-day feeding period. The steers did not scour, go off feed, or exhibit any other digestive disturbances and they did not appear abnormal in any way.

Arasan tended to depress feed consumption, whereas Orthocide did not. As the feed consumption of the steers fed Arasan treated corn decreased, gains decreased. Differences in feed consumption between

treatments were significant at the 5% level, however, differences in gain between treatments were not significant.

Based on the results obtained it is suggested that Arasan treated corn be processed to remove half of the original fungicide or mixed with non-treated grains so that the daily consumption of Arasan will not furnish more than 125 mg. of tetramethyl thiuram disulphide per 100 lb. of liveweight for yearling steers. In this investigation fattening yearling steers tolerated 725 mg. of captan per 100 lb. of liveweight daily. However, at this level feed consumption was depressed, but gains and the efficiency of feed utilization were not.

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A URINE AND FECES COLLECTING APPARATUS FOR HEIFERS AND COWS [1, 2]

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THE analysis of the excreta of farm animals has considerable importance in certain physiological and nutritional studies, especially digestion trials, balance studies and hormone assays. This has necessitated the development of apparatuses for the separate collection of feces and urine in cows and heifers.

In the past, manual collection, at a great cost in labor, or devices incorporating rather elaborate equipment, have been used. These devices are apt to be high in cost, to lack mobility, and to prevent the experimental animal from being maintained under normal herd environment. Attempts have been made to circumvent these conditions by the use of various types of urine and feces separating devices in conjunction with harnesses. Forbes *et al.* (1937) described an apparatus in which a rubber tube strapped over the vulva with a harness conducted the urine to a container near the cow. An apparatus also making use of a rubber tube to carry urine to a stationary container, but using branding cement to attach straps and tube to the animal, has been described by Hobbs et al. (1950). A similar device used at this station effectively collected urine, but the removal of the apparatus was rather difficult. Furthermore, when the apparatus was attached and removed every few days, the spots in which the straps were fastened by branding cement became raw and devoid of hair.

Balch *et al.* (1951) have modified an apparatus, first described by Ballinger and Dunlap (1946), which utilizes a harness with a feces-collecting bag and a rubber tube to conduct urine to receptacles set in the floor. The apparatuses described by Forbes *et al.* (1937), Hobbs *et al.* (1950) and Balch *et al.* (1951) have all operated effectively at this station. However, they have one disadvantage in common. With none of the three is it possible to collect feces and urine concurrently

[1] Washington Agricultural Experiment Stations, Pullman, Project 1053.
[2] This investigation was supported in part by funds provided for biological and medical research by the State of Washington, Initiative Measure No. 171.
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unless the animal is stanchioned. In addition, with the apparatus described by Balch *et al.* (1951), the weight and length of the rubber feces collecting bag (approximately 7.5 lb. and 43 in.) make it undesirable for use with unstanchioned animals. Recovery and cleaning of feces from the bag are difficult and time consuming and the cost of purchasing this apparatus from England (or having it duplicated in the U.S.) is rather high.

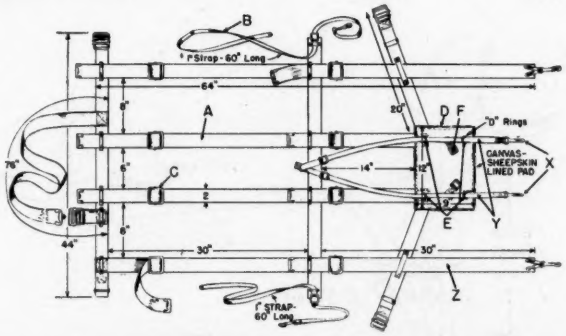

Figure 1. Supporting harness showing measurements and dimensions. A. Heavy weight, two-inch webbing. B. Heavy weight, one-inch bias tape. C. Two-inch metal webbing buckles. D. Rump pad (canvas sheepskin-lined pad). E. "D" rings. F. One-inch buckle. X. Bolt snaps. Y. One-inch webbing straps. Z. Side straps.

The apparatus herein described is a modification of the Balch apparatus, gaining mobility by the use of a portable urine bag and a smaller, lighter weight feces bag. In addition, the excreta are easily removed, the bags readily cleaned, and the costs are kept at a minimum by the use of local materials and labor. With this apparatus, feces and urine can be collected concurrently from unstanchioned animals in the barn or even animals on pasture.

Construction

Harness

The harness (figures 1 and 2) was made by a local tent and awning company [5] of two-inch webbing (type 3) as indicated in figures 1 and 2. A heavy weight, 1 in., bias tape (figure 1, B) was used for the straps passing underneath the hind legs. Two-inch metal web-

[5] Lewiston Tent and Awning Co., Inc., 215 18th St., Lewiston, Idaho.

bing buckles (figure 1, C) were used so that adjustments could be made for any normal-sized cow (800 lb. to 1700 lb.). The straps passing underneath the abdomen and crossing at the floor of the chest (figure 2) were designed to prevent irritation of the cow's mammary system.

The rump pad (figure 1, D) was constructed of heavy canvas over a sheepskin lining. This allows it to take on the contours of the animal's rump while still giving the needed support to the separating device.

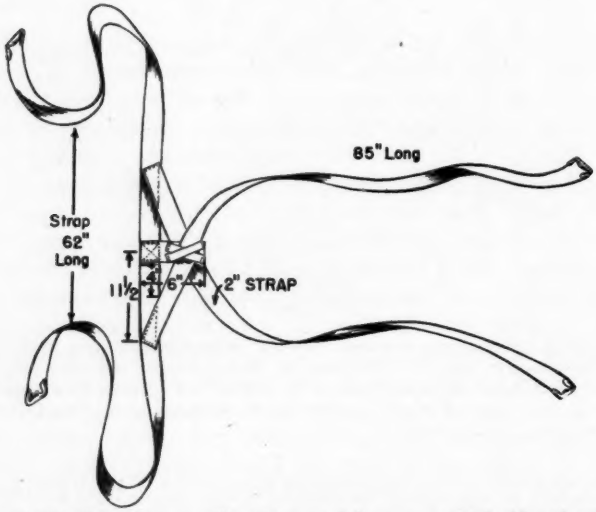

Figure 2. Portion of supporting harness lying on ventral side of animal.

Four D rings (figure 1, E), one on each corner of the rump pad, act as guides and points of attachment for other parts of the apparatus. The two one-inch buckles (figure 1, F) set obliquely on the rump pad are points of attachment for the feces bag hood.

Separator

The feces and urine separating device is basically a frame (figure 3) made of ⅛in. "form" wire or other pliable metal wire (painted with liquid neoprene, Gaco N-700, Gates Engineering Company, Wilmington, Delaware) covered with light weight canvas or unbleached muslin to form a funnel (figure 4). The lower funnel opening was made so that a piece of 2-in. radiator hose (figure 4, G) could be snugly fitted inside. The radiator hose acts to keep the lower end of the funnel open

and to give a solid support for attaching the urine bag. The separator was next painted over completely with two or three coats of liquid neoprene which waterproofs the separator and glues the canvas (or muslin) to the radiator hose. The separator apron (figure 5, H), made from an 18 x 24 in. piece of 3/64 in. rubber sheeting was fastened to the separator frame with liquid neoprene. To prevent a backflow of urine from the bag, a simple valve was devised (figure 6 I). It consisted of a piece of band tubing, (2.5 in. diameter x .031 in. thick, B. F.

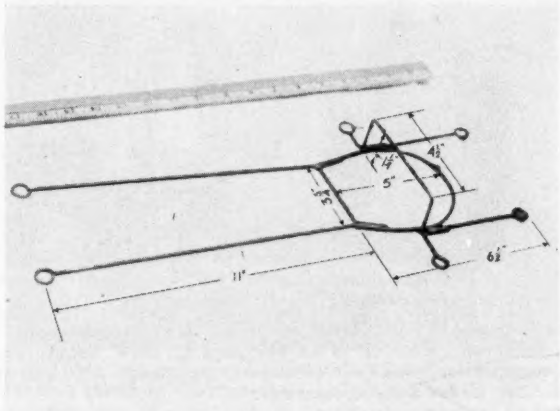

Figure 3. Wire frame supporting feces and urine separator.

Goodrich Co., Akron, Ohio) fitted over the end of the radiator hose, allowing a 4 to 6 in. piece to hang free.

Urine Bag

The urine bag can be made of a number of different materials and in numerous sizes and shapes. A satisfactory bag of simple construction (figure 7) can be made from 3/64 in. black cure-back tube gum. (Goodyear Tire and Rubber Company, Inc.).

The bag, as pictured, is basically a flat, hexagonally-shaped vessel with the top (figure 7, J) of the proper dimensions to form a short tube that will fit over the radiator hose of the separator. At the bottom, enough material is left to form another narrower tube (figure 7, K) to be used as an outlet.

The two sides of the bag are cut out of the cure-back tube gum and the covering of the uncured side peeled off except for a ½ in. strip

around the edges. The uncovered area is then cured by rubbing with resin. The covering is then peeled off the edges, the two sides brought together and sealed by pressing firmly together.

Eight belt loops, (figure 7, L) 4 on a side, which hold the straps that support the bag in place, are vulcanized to the bag.

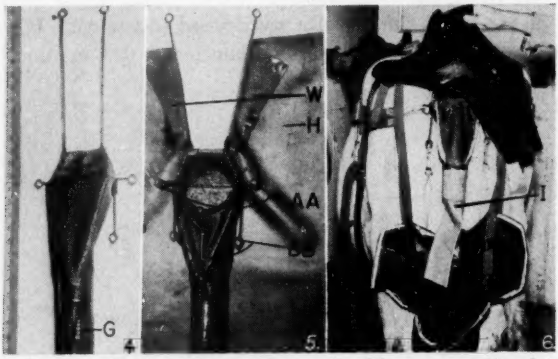

Figure 4. Feces and urine separator covered with canvas and painted with neoprene. G. Two-inch radiator hose.

Figure 5. Separator and rubber apron viewed from side facing animal. H. Rubber apron (made of 18" x 24" piece of 3/64" rubber sheeting). W. Upper separator arms bent outward to fit animal. AA. Side rings of separator. BB. Lower arms of separator.

Figure 6. Harness, apron, separator, and unassembled urine bag on cow. I. Valve (of band tubing to prevent urine backflow).

Feces Bag

The bag described herein was fabricated by a local tent and awning company.[6] The bags currently in use at this station, and which are giving very satisfactory service, are in two parts: (1) an outer supporting bag made of No. 10 duck canvas coated with a plastic (Pantasote) and (2) an inner polyethylene bag in which the feces are actually collected. The supporting bag is similar in general design to the feces bag described by Balch *et al.* (1951) except that it is somewhat shorter so that it does not strike the animals hocks while walking and is made of canvas rather than rubber. These two features considerably reduce the weight of the bag assembly and increase the comfort and mobility of the animal.

The supporting canvas bag (figure 9, M) is cylindrical in shape with

[6] Tacoma Tent and Awning Co., 607 S. 13th St., Tacoma, Wash.

an attached hood (figure 9, N) through which is a hole (figure 9, O) for the animal's tail. The hood portion of the bag is made of two layers of material—the outer one being the plastic coated canvas from which the remainder of the bag is made, whereas the inner facing is a nylon plastic material sold under the trade name of "Tuff Tarp".[6] This nylon

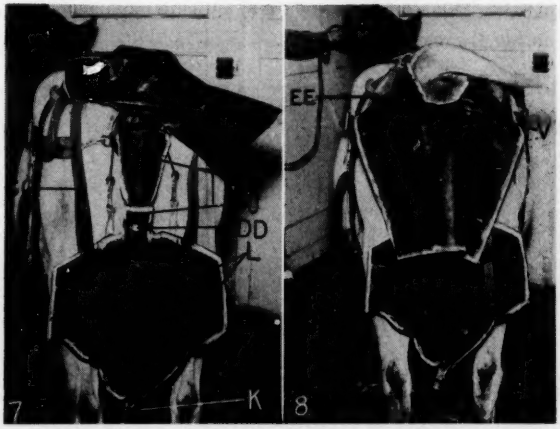

Figure 7. Urine bag in place showing relation of bag to separator and harness (apron raised to show details). J. Top opening of urine bag (fits around radiator hose of separator). K. Outlet of urine bag. L. Belt loops (hold straps that support bag in place). U. Separator in place over vulva. CC. One-inch webbing straps (support urine bag). DD. Thumb-screw type radiator-hose clamp (holds upper opening of bag in place over radiator hose of separator).

Figure 8. Harness, separator (not visible), apron and urine bag in place. V. Position of apron and separator in relation to tail and anus. EE. Slits in apron (allow urine bag supporting straps to pass through).

plastic is very tough and has the added feature of having a very slick and smooth surface to which feces do not adhere.

The nylon plastic should be cut approximately 5 in. longer than the duck canvas in order to form a flap that is used to secure the polyethylene bags in place. Two straps of one-inch webbing (figure 11, P) are sewn to the hood in such a manner that they will cross each other when attached to the buckles on the rump pad. These straps should be long enough to extend 10 in. beyond the edge of the hood.

When attaching the hood to the cylindrical portion of the bag, the lower 3 in. of nylon plastic is folded back on itself and inserted between

the two layers about 1 in. This will leave a double layer of nylon plastic extending 2 in. below the base of the canvas layer. The hood is then attached to the open end of the cylindrical portion of the bag by placing the nylon plastic layers on the inside of the bag and the canvas layer on the outside and sewing through the several thicknesses of material on a line approximately 2.5 in. above the folded edge of the nylon plastic. This provides a flap (figure 10, Q) of approximately 2.5 in. inside the bag.

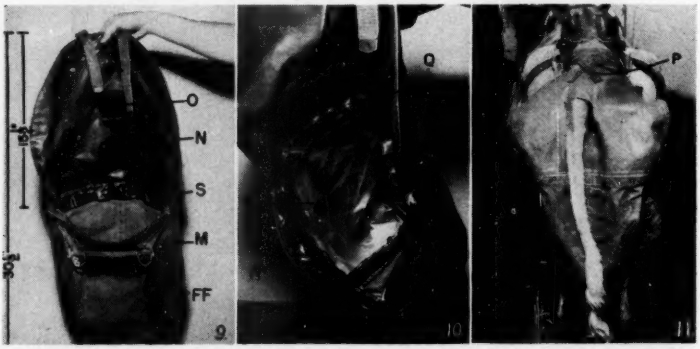

Figure 9. Details of feces bag viewed from side facing cow. M. Outer supporting bag (made of No. 10 duck canvas coated with a plastic). N. Hood of feces bag (supports cylindrical bag). O. Opening for animal's tail. S. Gripper snaps (hold inner polyethylene bag in place). FF. "D" rings (attached to bolt snaps of one-inch webbing supporting feces bag).

Figure 10. Close-up of feces bag showing polyethylene lining bag in place. Q. Flap of nylon plastic. R. Inside flap (female portion of gripper snaps are placed on this flap). T. Polyethylene lining bag.

Figure 11. Rear and top view of harness with feces and urine bag in place. P. One-inch webbing straps (hold hood of feces bag in place).

A similar inside flap (figure 10, R) is then made to extend around the remainder of the inside circumference of the top of the cylindrical portion of the bag by folding in half a 4-in. wide strip of the nylon plastic of the necessary length and sewing this to the top of the bag with the folded edge extending downward inside the bag.

These inner flaps of nylon plastic serve as a means of securing the inner polyethylene bag in place, and also direct the feces into the bag without loss. A series of 10 gripper snaps (figure 9, S) are attached, the female part to the flaps and the male portion to the walls of the canvas bag, so that one is superimposed over the other for easy closing.

Details of the hood and flap construction are shown in figures 9 and 10.

In use, polyethylene bags (figure 10, T) measuring 18 x 24 in. and of 2 mm. thickness have been very satisfactory as inserts in the supporting canvas bag for feces collections. After inserting the polyethylene bag into the supporting bag, the top edge of the polythylene bag is tucked up under the plastic bag. A plastic bag is shown in place in figure 10. Even though holes are punched through the plastic by the gripper snaps, this has proven a very effective means of fastening

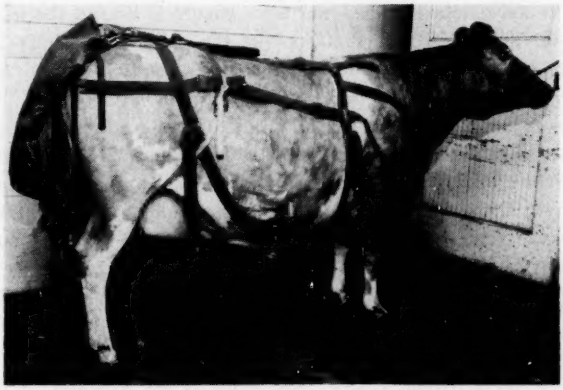

Figure 12. Side view of harness with feces and urine bag in place.

the bags in place. In a series of approximately 285 individual collections made at this station, with equipment as herein described, no failures were encountered as a result of torn plastic bags or from bags pulling out from under the flaps. The bags are easily removed by opening the gripper snaps, grasping the top of the plastic bag, and pulling it out of the supporting bag. The polyethylene bags may be reused a number of times. In experiments at this station these bags have averaged 8 collections per bag.

Assembling the Apparatus

In assembling the complete apparatus for operation (figures 11 and 12) the harness is placed on the animal, as pictured, with the straps adjusted to give firm support and still allow a maximum of comfort. The key point is to keep the rump pad in a fixed and steady position as it must bear a great proportion of the strain.

With the harness in place, the separator is then placed over the vulva, (figure 7, U) and figure 8, V) so that it is in the proper position to separate the feces from the urine. The upper separator arms (figure 5, W) are bent so as to curve over the pin bones on each side of the tailhead and to pass through the posterior D rings (figure 1, E) of the rump pad. They are then secured by bolt snaps (figure 1, X) to the 1-in. webbing straps (figure 1, Y) of the harness. The two side straps (figure 1, Z) are snapped to the side rings (figure 5, AA) of the separator and the 1-in. heavy bias tape (figure 1, B) is passed underneath the hind legs and snapped to the lower arms (figure 5, BB) of the separator. The 1-in. webbing straps that support the urine bag (figure 7, CC) are attached by bolt type fasteners to the posterior pair of D rings (figure 1, E) of the rump pad.

The urine bag is connected to the separator (figures 6 and 7) by slipping the rubber tube at the top of the bag (figure 7, I) over the band tubing valve and the radiator hose of the separator. It is fastened in place by a thumb screw type radiator hose clamp (figure 7, DD). To be sure the valve is hanging free in the bag, water is run through the separator into the bag.

One inch webbing straps passing through the belt loops and under the urine bag provide support for a large weight of urine. These straps pass through a slit (figure 8, EE) in the apron of the separator and are attached by means of bolt type snaps to the posterior D rings of the rump pad.

In attaching the feces bag, the tail is pulled through the tail hole (figure 9, O) of the hood on the feces bag and the bag is hung so that the separator apron (figure 4, G) hangs inside the bag. The main support of the feces bag comes from 1-in. webbing straps fastened to the D rings (figure 9, FF) of the feces bag with bolt type snaps. These straps pass upward and through the slits in the apron of the separator then anteriorly through both pairs of D rings of the rump pad (figures 11 and 12) and are fastened to the harness by passing through the two-inch buckles just anterior to the rump pad.

When first used on an animal, the apparatus should be checked frequently, especially after the animal has laid down. The operator is more apt to find the apparatus attached too tightly than too loosely in instances of poor separation of urine and feces. Work at this station with cows either in regular stanchions or loose in box stalls indicates that removal of the excreta three or four times daily is satisfactory under normal excretion patterns. If only one type of the excreta is to be

saved, the other bag may be removed and the excreta allowed to drop to the floor.

Summary

An apparatus that separately collects urine and feces from cows and heifers is described. It is mobile, relatively inexpensive and allows cows to be maintained under normal herd conditions.

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THE EFFECT OF DIFFERENT LEVELS AND PROLONGED SUPPLEMENTATION OF CHLORTETRACYCLINE UPON ROUGHAGE DIGESTION BY SHEEP [1]

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THE role of antibiotics in animal nutrition has been reviewed by Stokstad (1954), Brande (1953), Jukes and Williams (1953), Reid *et al.* (1954) and Lassiter (1955). Perry *et al.* (1954) and Elliott and Ellsworth (1953) have shown that chlortetracycline added to the rations of ruminants will stimulate gain and feed efficiency. Horn *et al.* (1955) reported that chlortetracycline added to the rations of steers in a metabolism study had no significant effect upon the digestibility of crude fiber. However, Bell *et al.* (1951) reported that high levels of chlortetracycline added to the rations of steers decreased the apparent crude fiber digestibility as much as 50%.

In view of these findings, this investigation was initiated to study the effect of varied levels, sources and prolonged supplementation of chlortetracycline on the digestibility of a ration composed chiefly of a low quality roughage.

Experimental Procedure

A series of three experiments was conducted in this invesigation of the effects of chlortetracycline supplementation in high roughage rations on apparent digestibility and nitrogen balance. The basal rations fed were composed of 80% ground corncobs, 14.61 soybean oil meal, 2.0 dehydrated alfalfa leaf meal, 2.0 molasses, 1.04 steamed bone meal, 0.35 salt (one ounce of cobalt sulfate added per 100 lb. of salt) and 0.01% vitamins A and D mixture, (10,000 I.U. of vitamin A and 500 I.U. of vitamin D per gram). The average calculated composition of the ration was: dry matter, 94.4%; crude protein, 9.1; ether extract, 1.1; crude fiber, 29.1; nitrogen free extract, 51.6; and ash, 3.5%.

[1] The investigation reported in this paper is published by permission of the director.
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[4] The authors wish to express acknowledgement to R. F. Elliott, Lederle Laboratories Division, American Cyanamid Company, Pearl River, New York, for the supply of chlortetracycline and to J. V. Whiteman, Department of Animal Husbandry, Oklahoma A. & M. College for aid with the statistical analysis.

Experiment 1

A series of three balance trials, each of which included three groups of two wethers each, were conducted with 18 wether lambs that weighed approximately 70 lb. each. After the wethers had become adjusted to feed and surroundings they were fed the basal ration for a 10-day preliminary period which was followed immediately by a 10-day collection period. The wethers in Group 1 received the basal ration; Group 2 received the basal ration plus 10 mg. of chlortetracycline per pound of ration; and Group 3 received the basal ration plus enough Aurofac 2A [5] to furnish 10 mg. of chlortetracycline activity per pound of ration.

Experiment 2

One balance trial was conducted with 20 wether lambs that averaged about 65 lb. each, which were divided into 5 groups of four wethers each on the basis of weight. These groups were then allotted at random to one of five treatments. Group I received the basal ration used in Experiment 1, Groups 2 and 3 received the basal ration plus 1 and 2 mg. of chlortetracycline respectively, and Groups 4 and 5 received the basal ration plus enough Aurofac 2A to furnish 1 and 2 mg. of chlortetracycline activity, respectively. The experimental continuity was essentially a repetition of Experiment 1.

Experiment 3

Experiment 3 was a repetition of Experiment 2 utilizing the same wethers on the same treatments. The levels of chlortetracycline were increased to 5 and 10 mg. per pound of ration and the Aurofac 2A levels were increased to furnish the aforementioned levels of antibiotic activity. Between Experiment 2 and Experiment 3 the wethers were placed in a holding pen and fed alfalfa hay free choice for 14 days. The experimental continuity of Experiment 3 was essentially a repetition of Experiment 1 except the collection period consisted of three consecutive 10-day collection periods.

The wethers were stanchioned in metabolism cages similar to those described by Briggs and Gallup (1949). The sampling and treatment of samples were conducted as set forth by Woods *et al.* (1955). Chemical analyses for dry matter, crude fiber, ether extract and crude protein (N×6.25) content of the ration constituents and feces and the nitrogen content of the urine were conducted by the methods of A.O.A.C. (1950).

[5] Contained 3.6 gm. of chlortetracycline per lb.

All data were analyzed statistically by analysis of variance (Snedecor, 1946).

Results and Discussion

Neither the 1 mg. nor the 2 mg. levels of chlortetracycline supplementation caused a decrease in feed consumption. However, the initial addition of chlortetracycline at 5-mg. and 10-mg. levels in all trials produced a loss of appetite within 40 to 72 hours after the initial supplementation. This condition was more severe in some of the wethers than in others, but all were back on feed in 72 to 96 hours. Jordon (1952)

TABLE 1. AVERAGE APPARENT DIGESTION COEFFICIENTS AND NITROGEN BALANCE FOR THREE TRIALS, EXPERIMENT 1

	Basal	Chlortetracycline[a] 10 mg.	Aurofac 2A[a] 10 mg.
Dry matter	64.0	57.2*	57.1*
Crude protein	62.1	60.4	61.4
Crude fiber	71.4	60.4**	59.7**
Nitrogen-free extract	61.5	55.5*	55.3*
Daily nitrogen retention, gm.	2.84	1.88	2.54

[a] To furnish 10 mg. of chlortetracycline per lb. of feed.
* Statistically significant at the 5% level.
** Statistically significant at the 1% level.

fed lambs chlortetracycline at levels from 7.2 to 14.4 mg. per lamb each day without loss of appetite. However, Colby *et al.* (1950) greatly reduced feed consumption with a daily dosage of 100 mg. of chlortetracycline per lamb. Bell *et al.* (1951) and Perry *et al.* (1954) found a similar depression of appetite in cattle. Provided this depressed appetite shown in *in vivo* studies was due to a shocking of rumen microorganisms it would be in agreement with the *in vitro* studies with chlortetracycline reported by Chandler and Bliss (1948).

The average apparent digestion coefficients for Experiments 1, 2 and 3 are shown in tables 1, 2 and 3, respectively. As shown by these data a significant decrease in apparent digestibility of organic matter, crude fiber and nitrogen-free extract attributed to chlortetracycline supplementation was evident in the three experiments. This reduction in the digestibility of ration constituents was of greater magnitude at the higher levels of supplementation, 10 vs 5, 2 vs 1 and 10 vs 5 for Experiments 1, 2, and 3 respectively.

Tillman and MacVicar (1953) using a single-reversal experimental design reported that chlortetracycline fed to wethers at the rate of 10

mg. per pound of feed had no effect on the apparent digestibility of ration constituents. Under those conditions a carry-over effect was possible. Bell *et al.* (1950) showed a decrease in apparent digestibility of dry matter and crude fiber by steers that were fed 200 mg. of chlortetracycline daily. Lassiter *et al.* (1954) reported similar results with steers that received 500 mg. of chlortetracycline daily. These findings are in agreement with the results of Experiments 1 and 2, and Period 1 of Experiment 3.

TABLE 2. AVERAGE APPARENT DIGESTION COEFFICIENTS AND NITROGEN BALANCE, EXPERIMENT 2

		Chlortetracycline[a]		Aurofac 2A[a]	
	Basal	1 mg.	2 mg.	1 mg.	2 mg.
Organic matter	62.3	60.9	57.7*	63.4	56.4**
Crude protein	62.3	63.3	61.1	64.4	61.8
Crude fiber	76.7	70.7*	65.9**	71.1	64.6**
Nitrogen-free extract	53.7	54.2	50.9	59.2	51.3
Daily nitrogen retention, gm.	1.65	0.43*	0.15*	1.45**	1.74**

[a] Antibiotic per lb. of feed.
* Statistically significant at the 5% level.
** Statistically significant at the 1% level.

As Experiments 1 and 2 had shown that chlortetracycline and Aurofac 2A decreased the apparent digestibility of ration constituents for a short period of time it was thought advisable to extend the studies in Experiment 3 over a longer time through three consecutive 10-day collection periods. In Experiment 3, table 3, the depressing effect of Aurofac 2A on the apparent digestibility of organic matter, crude fiber and nitrogen-free extract was more pronounced than that of crystalline chlortetracycline during Period 1. However, in Period 2 the wethers that received Aurofac 2A digested their ration constituents somewhat better than in Period 1 and the depressing effect of crystalline chlortetracycline was more severe in Period 2 than in Period 1. An improvement of the digestive efficiency of all groups supplemented with Aurofac 2A and crystalline chlortetracycline in Period 3 was evidenced by the fact that there were no significant differences in the apparent digestibility of ration constituents of the basal and treated rations during Period 3. The average reduction of apparent crude fiber digestibility for both sources of chlortetracycline at the 10-mg. level for Periods 1, 2 and 3 were 18.4, 11.5 and 5.4%, respectively. This same pattern of recovery was followed by organic matter and nitrogen-free extract.

TABLE 3. EFFECT OF PROLONGED AUREOMYCIN SUPPLEMENTATION ON APPARENT DIGESTIBILITY AND NITROGEN BALANCE, EXPERIMENT 3

	Organic matter	Crude protein	Crude fiber	Nitrogen-free extract	Daily nitrogen balance
					gm.
		Period I			
Basal	63.6	62.9	73.0	58.8	1.24
Chlortetracycline[a]					
5 mg.	58.6	62.4	64.6*	54.8	1.34
10 mg.	57.1**	62.8	61.6**	53.7	1.58
Aurofac 2A[a]					
5 mg.	58.3*	62.0	65.8	53.8	1.46
10 mg.	53.0**	60.5	57.7**	49.2**	1.66
		Period II			
Basal	61.3	58.5	70.7	56.9	0.29
Chlortetracycline[a]					
5 mg.	59.5	64.3**	66.4	55.1	0.84
10 mg.	54.9**	58.4	61.2**	50.0**	0.41
Aurofac 2A[a]					
5 mg.	65.5	61.4	69.9	56.5	0.51
10 mg.	57.1	58.4	64.1*	53.1*	0.58
		Period III			
Basal	63.5	64.4	72.7	58.8	1.20
Chlortetracycline[a]					
5 mg.	62.9	65.9	71.0	57.9	0.47
10 mg.	59.5	64.7	66.6	54.9	0.41
Aurofac 2A[a]					
5 mg.	61.7	64.8	69.2	57.4	—0.03
10 mg.	63.7	66.0	71.0	59.4	0.02

[a] Antibiotic per lb. of feed.
* Statistically significant at the 5% level.
** Statistically significant at the 1% level.

Paine *et al.* (1948), using *in vitro* techniques, reported that the organisms studied showed no marked tendency to become resistant on repeated exposures to chlortetracycline, but a moderate increase in resistance did occur in some strains. Neumann *et al.* (1951) obtained results that indicated a much less diverse flora for chlortetracycline-treated animals than for the controls. If a less diverse flora developed in the rumina of the treated wethers in Periods 1 and 2, it might explain why the digestibility of the treated rations was reduced. Likewise, Hungate *et al.* (1955) using *in vitro* manometric techniques showed a

significantly greater decrease in formation of fermentation products upon addition of chlortetracycline to rumen contents of steers that had previously received no chlortetracycline than of steers that had previously received chlortetracycline. The rumen contents from steers that had previously received chlortetracycline formed fermentation products at the same rate as the rumen contents of steers that had received no chlortetracycline. Therefore, it appears that the significance due to period in Experiment 3 may have been caused by resistance developed by the rumen microorganisms to chlortetracycline supplementation or a change in rumen flora of the wethers that received the rations supplemented with the antibiotic.

Even though chlortetracycline altered the digestive processes of the wethers that received the antibiotic supplemented rations, a recovery of these microbial mechanisms to their previous level of efficiency was attained in Period 3 of Experiment 3. Although there is a trend toward a faster recovery for the Aurofac 2A supplemented group, there are no significant differences due to the source of chlortetracycline. This agrees with *in vitro* bacteriology studies with chlortetracycline made by Chandler and Bliss (1948). Johansson *et al.* (1953) reported that dietary chlortetracycline caused a rapid change within the intestinal microflora of the rat, with a large portion of the flora, notably coliforms, developing a resistance to antibiotics. This is in agreement with the work by Chance *et al.* (1953).

As Chandler and Bliss (1948), Paine *et al.* (1948), Johansson *et al.* (1953), and Saz *et al.* (1955) have reported that certain microorganisms have developed a resistance to antibiotics, these digestibility studies suggest that the rumen microorganisms in the chlortetracycline-treated groups of Experiment 3 also may have developed a resistance to chlortetracycline. Then as the flora recovered from the initial shock, a level of efficiency in the digestibility was reached which was equal to or slightly below the digestibility observed prior to chlortetracycline supplementation.

Summary

Three experiments were conducted with 38 wether lambs, that weighed an average of about 65 lb. each, to determine the effect of chlortetracycline on the apparent digestibility of feed constituents of a ration which consisted primarily of low quality roughage. The rations were composed of 80% ground corncobs and 20% concentrate mixture.

In Experiment 1 the basal ration was supplemented with 10 mg.

of chlortetracycline and chlortetracycline as Aurofac 2A per pound of feed. In Experiment 2 the basal ration was supplemented with chlortetracycline and chlortetracycline as Aurofac 2A, each at the 1 and the 2-mg. levels per pound of feed. Experiment 3 was a repetition of Experiment 2, except the levels of antibiotic fed were increased to 5 and 10 mg. per pound of feed, and the collection period consisted of three consecutive 10-day collection periods.

In all experiments the initial supplementation of 5 and 10 mg. of chlortetracycline or Aurofac 2A caused a loss of appetite within 40 to 72 hours. All levels of chlortetracycline supplementation significantly decreased the apparent crude fiber digestibility except the 1 mg. level of chlortetracycline as Aurofac 2A in Experiment 2. This same trend was present for dry matter, organic matter, and nitrogen-free extract. As the level of chlortetracycline was increased from one to two and from 5 to 10 mg. the decrease in apparent digestibility of ration constituents became greater. In Experiment 3 there was a definite period effect in the chlortetracycline supplemented groups with a recovery of apparent digestibility of ration constituents in Period 3. The average apparent digestibility of crude fiber for both sources of chlortetracycline at the 10-mg. level for Periods 1, 2 and 3 in Experiment 3 were reduced by 18.4, 11.5 and 5.4%, respectively. This same trend of recovery was present for dry matter, organic matter and nitrogen-free extract. The implications of these findings are discussed.

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FEATHER MEAL AS A SOURCE OF PROTEIN FOR FATTENING LAMBS [1]

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POULTRY feathers represent a large potential source of protein for feed use. Wilder *et al.* (1955) estimated that an amount in excess of 50,000 tons of feather meal containing about 87% protein would be available annually for feed use.

Romoser (1955) and Wilder *et al.* (1955) used various feather meals as substitute for part of the protein source in chick rations. Both researchers reported that growth response was as large or larger in the chicks fed rations containing feather meal than those fed the basal ration. Hall *et al.* (1955) reported an increase in cellulose digestion in artificial rumen studies when feather hydrolysate was added to the media. The same laboratory reported that the addition of 20 ml. of feather hydrolysate per pound of lamb ration increased rate of gain of fattening lambs. Jordan *et al.* (1955) fed feather meal to three lots of fattening lambs. One lot received a sub-optimum level of protein in the form of soybean oil meal, the second and third lots receiving equal amounts of protein at an optimum level. However, in lot 2 the protein was supplied in the form of soybean oil meal and in lot 3 the protein consisted of a mixture of 2 parts of ground corn, 1 part of soybean oil meal and 1 part of feather meal. Lots 2 and 3 gained at the same rate and had approximately the same feed efficiency but both gained decidedly faster than the lot fed the lower level of protein.

Concentration of the poultry business in certain areas and the trend towards consolidation of poultry dressing plants simplifies the collection of poultry feathers for processing into feather meal. At present, most feather meals are processed with 30 to 40 lb. of internal steam pressure. Another process involves the addition of 50 lb. of hydrated lime per ton of feathers. When the lime is added to the feathers, a friable meal can be made with no internal steam pressure.

The volume of feather meal, its high protein content and relatively low cost per unit of protein, makes it worthy of study to determine its value as a protein source for ruminants. The purpose of the experiment

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[2] The feather meal used in this experiment was kindly donated through the courtesy of Mr. James McDonald of Central Manufacturing Co., Wichita Falls, Texas.

reported herein was to determine whether commercially processed feather meal in which either the high pressure and steam or hydrated lime method is used, could be used as a protein source for fattening lambs.

Experimental Procedure

Trial 1

Sixty-four good quality Western feeder lambs, weighing approximately 75 lb., were divided into four lots of 16 lambs each and group-fed a fattening ration of low-quality timothy hay, shelled corn, minerals and protein supplement. The protein supplement fed to lots 1 and 2 was 0.3 lb. per lamb daily of solvent extracted soybean oil meal, (chemical analysis, 45.2% protein). The protein supplement fed to lots 3 and 4 was 0.4 lb. per lamb daily of a supplement consisting of 2 parts of ground corn, 1 part of soybean oil meal and 1 part of steam processed feather meal, (chemical analysis, 37.5% protein). Thus, the protein levels of the control and the experimental lots were about equal. The lambs were individually weighed biweekly and average daily feed consumption and feed efficiency were calculated. Individual carcass grade and yield was obtained on all lambs slaughtered.

Trial 2

Three lots of 10 lambs each of choice quality and western origin were full fed a ration consisting of low-quality brome grass hay, shelled corn, mineral, and the following protein supplements: Lot 1, 0.3 lb. of solvent extracted soybean oilmeal; Lot 2, 0.3 lb. of protein supplement containing equal parts of ground corn, solvent extracted soybean oil meal and steam processed feather meal, (chemical analysis, 49.2% protein); Lot 3, 0.3 lb. of protein supplement consisting of equal parts of ground corn and steam processed feather meal, (chemical analysis, 48.7% protein). Since the protein supplement was liberally fed, the slight difference in protein analysis for the three supplements should not have resulted in a shortage of protein intake in any of these lots. Methods of procuring data on this group of lambs was similar to that used in trial 1.

Trial 3

Five lots of 15 native lambs each, of medium quality, were full fed a ration of low-quality timothy hay, shelled corn, minerals and the

following supplements: Lot 1, 0.25 lb. of solvent extracted soybean oil meal; Lot 2, 0.25 lb. protein supplement consisting of one half ground corn and one half steam processed feather meal, (chemical analysis, 48.7% protein); Lot 3, 0.25 lb. protein supplement containing equal parts of steam processed feather meal, ground corn, solvent extracted soybean oil meal, (chemical analysis, 49.2% protein); Lot 4, 0.25 lb. protein supplement consisting of equal parts of ground corn, lime processed feather meal and solvent extracted soybean oil meal, (chemical analysis, 48.4% protein). Two lambs in lots 1, 2 and 3 and one lamb in lot 4 showed evidence of pregnancy before the trial was completed.

TABLE 1. FEATHER MEAL IN LAMB RATIONS

	Trial 1		Trial 2		
Treatments[a]	Control Lot 1	Corn soy F. meal Lot 2	Control Lot 3	Corn soy F. meal Lot 4	Corn F. meal Lot 5
Comparisons					
No. lambs	32	32	10	10	10
Initial av. wt., lb.	73.4	75.2	66.0	66.3	66.8
Final av. wt., lb.	90.1	93.7	106.4	104.0	107.3
Gain per lamb, lb.	16.7	18.5	40.4	37.7	40.5
No. days fed	56	56	98	98	98
Av. daily gain, lb.	.298	.332	.412	.384	.413
Av. daily feed consumption, lb.					
Corn, shelled	1.61	1.51	1.56	1.54	1.52
Hay[b]	1.25	1.28	1.16	1.16	1.15
Protein supplement	.30	.40	.30	.30	.30
Feed per 100 lb. gain, lb.					
Corn, shelled	540.0	456.0	378.0	400.0	369.0
Hay[b]	419.0	385.0	282.0	302.0	278.0
Protein supplement	100.0	121.0	73.0	78.0	73.0
Carcass data[c]					
Yield, %	52.3	52.1	53.4	53.9	52.5
Grade	6.77	6.22	6.20	6.10	5.90

[a] Lots 1 and 3: Soybean oil meal.
Lot 2: Two parts ground corn, 1 part soybean oil meal and 1 part steam processed feathers.
Lot 4: Equal parts of ground corn, soybean oil meal and steam processed feather meal.
Lot 5: Equal parts of ground corn and steam processed feather meal.

[b] Timothy hay in trial 1; Brome grass hay in trial 2.

[c] Carcass yield is based on warm carcass weights. Carcass grade was coded with high good equal to 6, low choice=7, medium choice=8, etc.

TABLE 2. FEATHER MEAL IN LAMB RATIONS

Treatments[a]	Trial 3			
	Control Lot 1	Corn F. meal Lot 2	Corn Soy F. meal Lot 3	Corn Soy F. meal Lot 4
Comparisons				
No. lambs	13	13	13	14
Initial av. wt., lb.	73.3	73.6	74.0	73.6
Final av. wt., lb.	95.8	98.1	97.4	95.6
Gain per lamb, lb.	22.5	24.5	23.4	22.0
No. days fed	56	56	56	56
Av. daily gain, lb.	.400	.437	.418	.393
Av. daily feed consumption, lb.				
Corn, shelled	1.39	1.36	1.38	1.38
Timothy hay	1.19	1.13	1.17	1.13
Protein supplement	.25	.25	.25	.25
Feed per 100 lb. gain, lb.				
Corn, shelled	349.0	313.0	330.0	347.0
Timothy hay	298.0	260.0	280.0	285.0
Protein supplement	64.0	58.0	60.0	65.0

[a] Lot 1: Soybean oil meal.
Lot 2: Equal parts of ground corn and steam processed feather meal.
Lot 3: Equal parts of ground corn, soybean oil meal and steam processed feather meal.
Lot 4: Equal parts of ground corn, soybean oil meal and lime processed feather meal.

The weight gains for these lambs are not included in the data. However, the data for average feed consumption does include the feed eaten by these lambs. It was arbitrarily assumed that their feed consumption would not differ greatly from the other lambs. Carcass data were not obtained on the lambs in this trial because of this pregnancy factor.

Results and Discussion

The results of trials 1 and 2 are presented in table 1. Because these data are almost identical for the replications in trial 1, the two replications are averaged and presented as one control lot of 32 lambs and one feather-fed lot of 32 lambs, rather than four lots of 16 lambs each. The results of the third trial are presented in table 2.

Feed Consumption

The feather meal, whether it was processed with steam and relatively high pressure and heat or with lime and low heat and pressure, had the

odor of tankage. In these three trials, the odor apparently did not affect the average daily feed consumption as the consumption of the grain and protein supplement was almost identical for the basal ration and the feather-fed groups. For example, in the first trial, grain and protein consumption in the control lots of 1 and 2 was 1.91 lb. and 1.90 lb. respectively and in the feather meal fed lots, 3 and 4, grain and protein supplement consumption was 1.93 lb. and 1.90 lb. In the other two trials, consumption of the rations which contained steam processed feather meal or lime processed feather meal was essentially the same as that of the control rations. In a preliminary trial, Jordan *et al.* (1956) reported that lambs that were switched from a corn, alfalfa, soybean oil meal ration to a ration consisting of prairie hay, corn, minerals and soybean oil meal continued to eat well and gain well. Conversely, a switch from a ration of corn, alfalfa, and soybean oil meal to one of prairie hay, corn, mineral and protein supplement consisting of equal parts of ground corn, soybean oil meal and feather meal resulted in decidedly less grain intake and less average daily gain. In this preliminary trial, it took about two weeks for the lambs to get adjusted to the feather-meal ration. After that time, their gain and feed intake was similar to the control lambs. Therefore, it appears that if feather meal is to be used as a protein supplement, it should be fed from the beginning of the feeding period.

Rate of Gain

In the first trial, the rate of gain of both lots fed a protein supplement containing steam processed feather meal exceeded the rate of gain made by the two control lots. The two control lots, lots 1 and 2, gained 0.296 and 0.298 lb. per lamb daily respectively, while the lambs receiving the feather meal in their supplement, lots 3 and 4, gained 0.338 and 0.325 lb. respectively. When the two control lots were averaged their rate of gain was 0.298 lb. per lamb daily in contrast to the average of the two replications for the feather meal fed lambs of 0.332 lb. There was sufficient variation between the lambs within the lots so that these differences did not prove statistically significant.

In the second trial, the control lambs gained 0.410 lb. per lamb daily, the lambs receiving a protein supplement consisting of equal parts ground corn, soybean oil meal and feather meal gained 0.384 lb. per lamb daily and the lambs which received a protein supplement consisting of one-half ground corn and one-half feather meal gained 0.413 lb. The lambs which received a protein supplement consisting of equal parts of ground corn and feathers gained as well as the controls and actually exceeded

the rate of gain of the lambs which received ground corn, soybean oil meal and feather meal in their protein supplement. This indicates that the protein in the feather meal is available and its quality is such that protein from other protein supplements is not necessary for fattening lambs to utilize the protein contained in feathers.

The results of the third trial, in relation to rate of gain, were very similar to the second trial. The control lambs gained 0.400 lb. daily, the lambs receiving a protein supplement consisting of equal parts of ground corn and feather meal gained 0.437 lb. and the lambs receiving a protein supplement consisting of equal parts of ground corn, soybean meal and feather meal gained 0.418 lb. In addition to these three lots, a fourth group of lambs was fed a protein supplement consisting of equal parts of ground corn, soybean oil meal and feather meal which was processed by the addition of 50 lb. of hydrated lime per ton of feathers. These lambs made a rate of gain of 0.393 lb. per day. None of the differences in rate of gain were statistically significant.

Since the feed consumed daily per lamb was virtually the same in all lots, within each trial, differences in feed efficiency reflected the differences in daily rate of gain and for the most part were not greatly different between the lambs fed the various feather meal rations and the control lots. Carcass grade and yield did not differ between the basal ration and the test rations.

Summary

Three trials involving a total of 145 lambs were conducted to determine the value of feather meal as a partial source of protein for fattening lambs. Two types of meal were fed; feather meal processed with high pressure and steam (3 trials) and feather meal processed by the addition of 50 lb. of hydrated lime per ton of feathers and no internal pressure (1 trial). The steam processed feather meal was fed in combination with ground corn and soybean oil meal or in combination with ground corn. The experiment indicated that while commercially processed feather meal has a tankage aroma, this odor was not objectionable to the lambs. Feed consumption was as great in the lots receiving feather meal as part of their protein supplement as that of the control lambs which received soybean oil meal. In the three trials, there were no significant differences between the rate of gain of the control lambs and (1.) lambs fed a combination of ground corn, soybean meal and feather meal, (2.) ground corn and feather meal or (3.) ground corn, soybean oil meal and lime processed feather meal. However, in

four of six comparisons, slightly greater gains were realized in the lots receiving feather meal in their rations. Average carcass grade and yield was essentially the same for the lambs fed the basal ration and those fed the test rations.

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FEED FROM SEWAGE. III. DRIED ACTIVATED SEWAGE SLUDGE AS A NITROGEN SOURCE FOR SHEEP[1]

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THESE experiments were undertaken to study the retention and digestion of nitrogen in ruminants fed a ration containing dried activated sewage sludge. Harris and Mitchell (1941b) found that urea nitrogen was utilized by sheep as a source of body protein. Johnson *et al.* (1944), using sheep, provided one line of evidence that urea is utilized through the synthesis of protein in the rumen. Loosli *et al.* (1949) showed that amino acids were synthesized in the rumen. These findings and those of other workers have helped explain why protein quality, as represented by amino acid make-up, is of limited importance in ruminant rations. The activated sludge process is an aerobic fermentation process in which the organic matter inherent in domestic sewage and the sewage from industries discharging organic wastes is metabolized and assimilated by a variety of microorganisms. The end product of this fermentation is a gelatinous mass of these microorganisms. Conditioning this mass with ferric chloride and drying results in a granular product. Although the dried solids are not completely sterile, the bacterial population is not any greater than that found in many food products. Bacteria of the coliform type are completely absent.

Preliminary to the work with ruminants, the amino acid composition of the protein of sewage sludge, and the biological value of the protein for the rat were determined.

Experimental Procedure

The 10 essential amino acids plus cystine, tyrosine, glycine and glutamic acid were determined by microbiological assay (Johnson, 1949) on three different lots of sludge. The biological value and the digestibility of the sludge protein for the rat were determined by the conventional Thomas–Mitchell Method (1924).

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In order to test the utilization of sewage sludge protein by the ruminant, nitrogen balance experiments were carried out on sheep. The experimental animals were six grade western wether lambs weighing between 55 and 64 lb., initially. They were placed on a 3×3 latin square design nitrogen balance and digestion experiment in which each lamb received in different periods each of the three experimental rations shown in table 1. Fresh rations were made up for each period. Each collection

TABLE 1. COMPONENTS OF THE EXPERIMENTAL RATIONS ON AN AIR-DRY PERCENTAGE BASIS

Ration	SBOM	Urea	Sludge
Prairie hay	40.00	40.00	40.00
Soybean oil meal	13.00	8.50	8.50
Urea		.70	
Dried activated sewage sludge			6.46
Corn starch		4.32	2.10
Ground corn	35.84	35.84	35.84
Cerelose	8.00	8.00	8.00
Wheat germ oil	.50	.50	.50
A and D concentrate	.22	.22	.22
Aurofac	.44	.44	.44
Steam bone meal	1.00	1.00	1.00
Iodized salt	1.00	1.00	1.00

period was of 7 days duration, preceded by a preliminary period of 14 days. During the last 3 days of the preliminary period the lambs were kept on a constant intake of feed, and this level was maintained as near constant as was possible throughout the collection period. The lambs were fed the experimental rations at levels to supply approximately the same crude protein (nitrogen×6.25) and caloric intake for each animal in each of the three collection periods.

Dried activated sewage sludge and urea were incorporated into the rations at the expense of soybean oil meal. They replaced the equivalent of 35% of the soybean oil meal protein. Thus in rations in which they were used they supplied approximately 18% of the total protein. Starch was added to the sludge and urea-containing rations at levels to make them isocaloric with the soybean oil meal ration. The percentages of crude protein, on the air dry basis, in the soybean oil meal, urea and sewage sludge rations were 12.1, 11.9 and 11.5, respectively.

During these metabolism experiments, the sheep were confined in metabolism crates of a design similar to that described by Bratzler (1951), whereby the feces and urine were collected separately. Urine

was collected daily in containers containing 10 ml. of 1.25% H_2SO_4. Daily collections of feces were dried at 120° F. for 100 hours.

Results

The average amino acid composition of the dried activated sewage sludge is given in table 2. The biological value calculated from these data by the modified essential amino acid index method of Mitchell

TABLE 2. AMINO ACID CONTENT OF SEWAGE SLUDGE

Amino acid	Percentage of Sludge	Percentage of Protein
Arginine	1.1	3.35
Histidine	0.44	1.34
Isoleucine	1.4	4.26
Leucine	1.8	5.48
Lysine	1.3	3.95
Methionine	0.5	1.52
Cystine	0.2	0.61
Phenylalanine	1.6	4.87
Tyrosine	0.7	2.13
Threonine	1.5	4.56
Tryptophan	0.25	0.76
Valine	2.0	6.08
Glycine	1.55	4.71
Glutamic acid	2.9	8.8
Moisture	4.5	
N, dry basis	5.26	
Ash, dry basis	38.0	

(1954) is 50. The determination of the biological value by the Thomas–Mitchell Method (1924) was difficult due to the extreme unpalatability of the ration for the rats. The sludge was tested against ground beef as experimental control, both rations being made up to contain 10% protein (N×6.25). The ground beef nitrogen had a digestibility of 89% and a biological value of 76, while the nitrogen of the sludge had a digestibility of 52% and a biological value for the animals which ate satisfactorily of 51.

The results obtained in the nitrogen balance experiment on sheep are summarized in table 3. Each datum is an average of six determinations on six animals. The biological value of the nitrogen in the rations was estimated on the assumption of a metabolic fecal nitrogen output of 0.555 gm. per 100 gm. dry matter consumed and an endogenous urinary

nitrogen output of 0.033 gm. per kilogram body weight (Harris and Mitchell, 1941a). The net availability of the nitrogen in the rations was calculated as the average apparent digestibility × the biological value × 100.

Discussion

From the amino acid composition of the sludge (see table 2) it was found that the limiting amino acid in the sewage sludge was methionine-cystine which was present at only one-third the level present in whole

TABLE 3. NITROGEN BALANCE DATA ON SIX LAMBS
(Average of three 7-day periods)

Ration	SBOM	Urea	Sludge
N intake, 7 days, gm.	102.2	98.4	102.3
N in feces, 7 days, gm.	34.5	32.8	46.6
N in urine, 7 days. gm.	44.0	43.4	33.4
N retained, 7 days, gm.	23.7	22.2	22.3
N retained, %	23.2	22.6	21.8
Apparent digestibility of N, %	66.4	66.8	54.6*
Biological value of N	60	60	69*
Net apparent availability of N	40	40	38

* Significantly different from soybean meal and urea ration $P<.001$.

egg protein (Mitchell, 1954) and that all of the nine essential amino acids, with the possible exception of threonine, were present in inadequate amounts compared to egg. Possibly the low biological value and poor digestibility precludes sewage sludge from consideration as a useful protein for the feeding of swine or poultry. On the other hand, it seemed logical to consider the possibility of using the sludge as a nitrogen source for the ruminant. Feed consumption was not affected by the addition of sludge to the ration in these experiments.

When the sewage sludge was fed in nitrogen balance experiments with sheep, no statistically significant difference in nitrogen retention was found between the sludge and the other nitrogen sources used.

The most interesting phase of the results is the observation that the digestibility of total protein of the sludge ration was about 55% as compared to 66% for the soybean ration; at the same time, the biological value of nitrogen was 69, resulting in nitrogen retention equal to that of the soybean ration and a lower urinary loss.

A possible explanation of these results may be that the sludge, being a fermentation product, contains some factor(s) which affect the rumen

fermentation and rumen biosynthesis of protein in such a way as to produce a protein of higher biological value. Further work on this possibility is planned.

Summary

A ration in which 18% of the nitrogen was supplied as dried activated sewage sludge was found equal, as measured by nitrogen retention, to soybean oil meal and urea-containing rations of similar crude protein content (11–12%). The total nitrogen of the sludge-containing ration had a significantly lower apparent digestibility and a higher biological value.

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FACTORS AFFECTING BIRTH WEIGHTS OF CROSSBRED LAMBS

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A POSITIVE relationship between birth weight and subsequent weights of lambs has been extensively studied and reported in the literature. deBaca *et al.* (1956) reported an increase of 2.50 to 5.96 lb. at weaning for every pound increase in birth weight. These estimates were similar to those of Cadmus (1949) and Phillips and Dawson (1937). Bonsma (1939) found a correlation coefficient of 0.41 between birth and twelve-week weights of lambs. Hammond and Appleton (1932) observed a correlation coefficient of 0.52 between one-week and twenty-week weights of lambs, and a still higher correlation of weight at 20 weeks with weight at 61 weeks. Dahmen and Bogart (1952) found a correlation coefficient between birth weight and economy of gains in beef calves of 0.42. Moreover, Bonsma reported a correlation coefficient of 0.32 between total milk yield of ewes and the birth weights of their lambs. He suggested that the same physiological functioning which was responsible for improved efficiency of food utilization instigates higher intra-uterine nutrition and no doubt improved mammary gland development, thus resulting in lambs heavier at birth and weaning. Bonsma (1939) and deBaca *et al.*, (1956) asserted that a large portion of the differences in weaning weights of crossbred lambs was due to differences in birth weights.

Heritability estimates of lamb birth weights of 0.33 and 0.25 to 0.30 have been reported by Nelson and Ven Katachalam (1949), Chapman and Lush (1932) and Blackwell and Henderson (1955). Yao *et al.*, (1953) reported estimates of heritability for birth weight of Karakul sheep ranging from 18 to 35%. Estimates for beef cattle within the same range have been reported by Burris and Blunn (1952) and Knapp and Nordskog (1946).

With these observations in mind a breeder could use birth weights as early measurements in selection, particularly in cases of flock reduction. Also, certain lambs might be castrated at birth with only the

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better ones retained intact from which males for breeding could be selected. A knowledge of what factors affect birth weights of lambs is necessary for proper use of birth weight as a selection criterion.

Materials and Methods

The data used in this study are from the Oregon State College sheep improvement program. The lambs were born during the winters of 1952 and 1953. The study is based on 224 matings and the resulting 280 lambs.

The dams of these crossbred lambs were also crossbreds, as the objective of the project was to ascertain which of several breed crosses were most adapted for optimal production under western Oregon conditions. The "first-cross" ewes referred to in this study were the result of mating Lincoln × Rambouillet ewes to Hampshire, Border Leicester, Cheviot and Romney rams. These ewes were 3, 4 and 5 years old the

TABLE 1. NUMBERS OF LAMBS WEANED ASSEMBLED ACCORDING TO YEAR, BREED AND TOP-CROSS OF EWE, BREED OF SIRE, SEX, AND TYPE OF BIRTH

Items	Suffolk sired	Southdown sired	Wethers	Ewes	Twins	Singles
1952						
First cross ewes						
Hampshire	10	5	7	8	6	9
B. Leicester	11	6	8	9	10	7
Cheviot	10	7	9	8	8	9
Romney	10	7	6	11	10	7
Second cross ewes						
Hampshire	13	6	9	10	14	5
B. Leicester	10	3	4	9	6	7
Cheviot	10	4	5	9	4	10
Romney	9	2	4	7	2	9
1953						
First cross ewes						
Hampshire	12	12	11	13	17	7
B. Leicester	12	12	13	11	17	7
Cheviot	11	11	10	12	12	10
Romney	8	9	9	8	9	8
Second cross ewes						
Hampshire	10	9	5	14	10	9
B. Leicester	10	8	11	7	10	8
Cheviot	9	10	9	10	6	13
Romney	8	6	10	4	2	12

first year and 4, 5 and 6 years old the second year of the study. The "second-cross" ewes were derived by backcrossing the first-cross ewes to rams of their respective sire breed (Hampshire, Border Leicester, Cheviot or Romney). These ewes were 2, 3 and 4 years old the first year and 3, 4 and 5 years old the second year of the study. The sires of the lambs were either of the Southdown or Suffolk breeds (deBaca, 1954).

Management of the flock was conducted in accordance with recommended commercial practices for western Oregon. The sheep were run on pasture at all times and were allowed the best pastures during breeding and while nursing lambs. Limited grain and alfalfa hay were fed

TABLE 2. ESTIMATED CONSTANTS AND THEIR STANDARD ERRORS FROM THE ANALYSIS OF BIRTH WEIGHT

	1952		1953	
Effect	First cross	Second cross	First cross	Second cross
Mean	9.96±.26	7.84±.26	9.99±.09	9.59±.22
Suffolk sire	.34±.33	−1.30±.50	.16±.12	.20±.36
Southdown sire	−.34±.33	1.30±.50	−.16±.12	−.20±.36
Hampshire ewe	.40±.60	−1.08±.54	.24±.13	.06±.42
B. Leicester ewe	.15±.53	.93±.66	.34±.14	1.28±.42
Cheviot ewe	.09±.49	−.59±.59	−.49±.14	−1.20±.38
Romney ewe	−.64±.50	.75±.73	−.09±.18	−.16±.47
Suffolk×Hampshire	−.19±.36	.86±.32	−.06±.09	−.04±.27
Suffolk×Border Leicester	.39±.33	−.13±.39	.14±.10	−.40±.28
Suffolk×Cheviot	−.22±.29	.20±.34	.16±.10	.52±.27
Suffolk×Romney	.04±.30	−.92±.40	−.22±.13	−.07±.31
Southdown×Hampshire	.19±.36	−.86±.32	.06±.09	.04±.27
Southdown×Border Leicester	−.39±.33	.13±.39	−.14±.10	.40±.28
Southdown×Cheviot	.22±.29	−.20±.34	−.16±.10	−.52±.27
Southdown×Romney	−.04±.30	.92±.40	.22±.13	.07±.31
Single	1.20±.30	1.18±.26	.96±.16	.96±.24
Twin	−1.20±.30	−1.18±.26	−.96±.16	−.96±.24
Ram	.28±.27	.34±.29	.44±.08	.42±.28
Ewe	−.28±.27	−.34±.29	−.44±.08	−.42±.28
Single×ram	.12±.22	−.13±.20	−.19±.04	.01±.17
Single×ewe	−.12±.22	.13±.20	.19±.04	−.01±.17
Twin×ram	−.12±.22	.13±.20	.19±.04	−.01±.17
Twin×ewe	.12±.22	−.13±.20	−.19±.04	.01±.17
Multiple Correlation coefficient	.56	.54	.90	.53
Number of animals	66	58	87	70

during lambing. All nutritional and climatic conditions were considered random or free from bias.

Each observation consisted of a weight taken to the nearest one-tenth of a pound within 5 hours after birth of the lamb. The least squares method of estimation was used in the analyses of the data to contend with the multiple classification and unequal subclass numbers (Anderson and Bancroft, 1952). Each observation for birth weight was assumed to be the sum of the effects of the identifiable variables. Birth weight is the sum of the effects listed in table 2.

This linear combination of effects is referred to as the mathematical model (deBaca, 1954). Restrictions are imposed upon the model, in that effects, other than the overall or mean effect, represent deviations from the overall effect. The constants estimated represent deviations from the mean effect which must be added to or subtracted from it (depending on their sign) to estimate birth weight.

The number of lambs are listed in table 1 according to their various classifications.

Results and Discussion

Estimates of the deviations, from the mean birth weight of the mathematical model, of the breed groups and environmental effects are presented in table 2. The difference between birth weights of lambs sired by rams of Suffolk and Southdown breeds lacked significance in three analyses (table 2). A significant difference occurred in the fourth analysis in which lambs by Southdown sires were heavier at birth than those sired by Suffolk rams. This situation seems unlikely and may have been due to chance. The only instances of consistent breed differences in birth weight were those in which lambs from Border Leicester-cross ewes were repeatedly heavier at birth than lambs from Cheviot-cross ewes, and lambs from Hampshire-cross ewes were heavier than those from the Cheviot-cross ewes when all lambs were sired by Suffolk rams. No significant differences existed among birth weights of lambs from Hampshire, Border Leicester or Romney-cross ewes nor between birth weights of Romney and Chevoit-cross lambs. The size of the unmeasured portions of variation (error) evidenced in these analyses suggests that a large portion of the variation was due to productivity of individual ewes within the breed. Perhaps the differences between individual ewes within a breed group was so great that they overshadowed the effect of breed (of ewe) and even the potential effects of sire breed. Bonsma (1939) observed that genetically, the birth weight

of lambs as influenced by the sire is determined by its hereditary size and earliness of maturity, and also that 24% of the birth weight variation was due to variation in ewe weight. Kincaid, moreover, attested that 7.8% of lamb birth weight variation was due to breed of sire. The effect of ewe weight was removed in these analyses only inasmuch as it was confounded with breed.

Birth type contributed the most consistent of all effects on birth weights. Singles were from 1.92 ± 0.48 to 2.40 ± 0.60 lb. heavier at birth than were twins. The differences and standard errors between singles and twins were remarkably similar among ewes of various top crosses within years.

The second-cross lambs were lighter at birth in 1952 than in 1953. An empirical explanation (solely from recollection) is that the ewes were carrying less condition prior to the lambing season of 1952 than in that of 1953; consequently, the intra-uterine environment may have been inferior in 1952. Apparently the first-cross ewes were more capable of withstanding the adverse conditions of 1952 than were the second-cross ewes.

The differences between birth weights of ram and ewe lambs were consistent. The trend in all cases was for ram lambs to be heavier; however, significance resulted in only one of four analyses. The interactions between birth type and sex were likewise inconsistent and unimportant.

It would appear that castrating the smaller lambs at birth with only the larger ones retained from which breeding animals are selected would be a sound procedure only if a correction is made for differences in birth weights which are due to twinning.

Summary

Suffolk and Southdown rams were mated to ewes of predominantly Hampshire, Border Leicester, Romney and Cheviot breeds. The resulting 280 lambs were weighed to the nearest one-tenth of a pound soon after birth. Analyses were conducted to determine the effect of breeds, breed-cross interaction, birth type, sex and birth type-sex interaction on birth weights of the lambs.

There was no consistent difference in birth weights of lambs sired by Suffolk and Southdown rams. Lambs from Border Leicester-cross ewes were significantly heavier than those from Cheviot-cross ewes. Hampshire-cross ewes produced lambs which were heavier than those from Cheviot-cross ewes when all lambs were sired by Suffolk rams.

There were no significant differences among birth weights of lambs from Hampshire, Border Leicester and Romney-cross ewes nor between those from Romney and Cheviot-cross ewes.

Birth type contributed the most consistent of all effects on birth weights. Singles were from 1.92 to 2.40 lb. heavier at birth than were the twins. Moreover, year differences in birth weights were apparent.

Consistent but small differences existed between the birth weights of ram and ewe lambs.

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ENVIRONMENTAL TEMPERATURE AND FERTILITY OF SOUTHDOWN RAMS EARLY IN THE BREEDING SEASON [1]

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QUALITY of semen produced by rams of some breeds of sheep has been found to be markedly lower during the summer months than during other seasons of the year (McKenzie and Berliner, 1937). In a study of ewes bred by Southdown rams early in the breeding season, Dutt (1954) found that failure of fertility and early embryonic death were the principal causes of a low rate of conception. Failure of ewes to ovulate was not an impotrant factor. In a later study (Dutt and Bush, 1955) reported that the semen quality was significantly improved and that fewer services were required to settle ewes by rams kept at lower environmental temperatures during the summer months. Since high environmental temperatures are associated with the period of poor semen quality in rams, it is of interest to study further the effect of environmental temperature on fertility of rams.

The present study was carried out in order to compare early in the breeding season semen quality and fertility level of rams kept in an air-conditioned room at 45–48° F. during the summer months with those of rams kept at uncontrolled temperatures. Fertility rate and early embryonic death loss in ewes bred with semen from treated and control rams were studied.

Materials and Methods

Low environmental temperature was maintained for the rams by keeping them in a well-insulated, air-conditioned chamber with natural light conditions provided by unshaded windows on the east and west exposures. A more complete description of this chamber is given by Dutt and Bush (1955). Temperature in the air-conditioned chamber was maintained constantly at 45–48° F. and the relative humidity at 70–80%. A room without temperature and humidity control, the same size as the air-conditioned room, was made available for control rams treated the same nutritionally as the rams in the air-conditioned room. The monthly average maximum temperatures at the nearby airport were

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83.4°, 89.0°, 88.5°, and 78.8° F. for June through September. Air temperature in the control room never varied more than a few degrees from the temperature reported at the airport.

Six purebred Southdown rams were randomly divided into a treated and a control group of three rams each. The two groups were kept in their respective rooms from June 2 until all ewes had been bred one time. Weekly semen collections for laboratory study were taken from the rams in an artificial vagina. Semen volume was recorded to the nearest 0.1 cc. Initial motility was estimated by examining a drop of semen diluted with Krebs solution on a slide under a high-power microscope. Estimates of percent motile cells were made at intervals of 10%. Percent of morphologically abnormal cells was calculated by counting the abnormal-shaped cells on the hemacytometer from which the cell concentration was determined.

One hundred and twenty yearling Hampshire-cross Western ewes were used in the fertility studies and in estimating the embryonic death loss. The breeding period was August 22 to September 25. Ewes were paired as they came into estrus, and alternate pairs were randomly chosen to be bred artificially with semen from either a control or a treated ram.Thus, each ram furnished semen to breed 20 ewes—10 ewes that were slaughtered for fertility data and 10 ewes kept for lambing data. Each member of a pair of ewes was artificially inseminated with 0.2 cc. of a split portion of whole undiluted semen deposited in the anterior vagina without the aid of a speculum, and one member was randomly selected to be slaughtered 3 days after breeding. The ova were flushed from the oviduct and examined on a hanging drop slide under the high power of a microscope, for cleavage. The other member was checked daily for return to heat until lambing.

The slaughter group of ewes thus furnished information on the fertilization rate, and the control group, information on the lambing rate and embryonic death loss. Embryonic death loss is calculated to be the difference between the fertilization and the lambing rate.

Results and Discussion

Semen Quality

The quality of semen from the rams in the air-conditioned room was considerably better than that produced by the control rams. Data for weekly averages of volume, percent motile cells, sperm cell concentration and percent abnormal cells for the breeding period are presented

in table 1. These averages are based on six weekly collections taken during the period August 20 to September 24, which includes the breeding period. There was no significant difference in the volume of semen produced by the two groups of rams during this period, although the treated group did produce a higher average volume. Part of the difference in volume can possibly be accounted for by lower sperm cell concentration from the control rams. Rams from both groups readily served the artificial vagina.

The greatest difference between the semen from the two groups of rams was in percent motile cells and in percent of morphologically

TABLE 1. AVERAGES OF SEMEN CHARACTERISTICS FOR WEEKLY COLLECTIONS AUGUST 22 TO SEPTEMBER 24 FROM CONTROL RAMS AND FROM RAMS KEPT IN THE AIR-CONDITIONED ROOM

Ram group	Vol.	Mot. cells	Cell conc.	Abnormal cells
3 rams/gr.	ml.	%	10,000/mm³	%
Control	.77±.03	41.8±2.7	243.3±31.5	36.9±6.6
Air-conditioned	.98±.08	70.3±1.4**	343.7±10.5*	6.4±0.5**

* Difference significant at 5% level.
** Difference significant at 1% level.

abnormal cells. The average motility for the control group was 41.8± 2.7% and for the treated group, 70.3±1.4%. The control group had an average of 36.7±6.6% of abnormal cells, and the treated group 6.4±0.5%. The larger standard error of the means of these two characteristics for the control group is largely due to seasonal changes in these traits during the period of the weekly tests. During the six-week collection period there was a gradual increase in the percentage of motile cells and a decrease in percentage of abnormal cells from the control rams. The variation in these characteristics for the rams in the air-conditioned room is due principally to variation among rams and very little was due to seasonal change. The difference in motility and percent of abnormal cells between the two groups was highly significant.

Sperm cell concentration in the semen from the treated rams was significantly higher than from the control rams (3.4 vs. 2.4 million cells per mm³). The standard error of the mean for sperm cell concentration from the control rams was three times as large as that for the treated group. The greater variation in the control group was again due primarily to a gradual increase in sperm cell concentration as the breeding period progressed. Rams kept in the air-conditioned room

during the summer months did not show the lowered motility and sperm cell concentration and the high percentage of morphologically abnormal cells found in the semen from rams kept at uncontrolled temperatures.

The poor quality of semen produced by the control rams is apparently due to the detrimental effect of summer temperatures on spermatogenic activity. Changes in semen quality after exposure of rams to high environmental temperatures reported by Phillips and McKenzie (1934), McKenzie and Berliner (1937), and Dutt and Hamm (1955) would also lend evidence to support this conclusion. Rectal temperature, pulse, and respiration rates of rams were taken on alternate days between July 20 and July 29, inclusive. The average rectal temperatures were 104.0° F. and 102.2° F. for the control rams and those in the air-conditioned room, respectively; average respiration rates were 150 per minute and 38 per minute. These differences are both highly significant. Pulse rates for the two groups of rams did not differ significantly. Rectal temperature, pulse, and respiration rates for ewes maintained under environmental conditions similar to those of the rams in this study have been reported (Dutt and Bush, 1955).

Fertility Rate

Anderson (1945) and Branton *et al.* (1951) have reviewed the literature pertaining to laboratory tests for evaluation of semen. From these reviews it appears that no single laboratory test having a high predictive value of potential fertility is available. It appears important therefore to have fertility data based on cleaved ova in evaluating the effect of ambient temperature on the fertility level of the two groups of rams.

Breeding was started as soon as the sexual season began for the ewes. The ewes were checked daily with aproned teaser rams, and were considered to be in heat when they would allow the ram to mount. The average dates of breeding for the ewes bred to the control rams and to the rams which were kept in an air-conditioned room were September 9 and September 11, respectively. Therefore, any effect of seasonal change in the environment of the reproductive tract of the ewe would tend to be equal in the two groups of ewes. The percentage of fertilized ova from the slaughter group of ewes bred by each of the rams is given in table 2. Of the 50 ova which were recovered from the slaughtered ewes bred to control rams, 26.0% were fertilized. The percentage of ova fertilized by the three rams in this group ranged from 18.7 to 31.2. Of the ewes bred to the rams in the air-conditioned room, 64.2% of

53 ova were fertilized, the percentage of ova fertilized ranging from 52.6 to 82.4. When tested by Chi-square, the difference in fertility between the two groups of ewes was highly significant.

The significantly higher percentage of ova fertilized by the rams in the air-conditioned room might be expected, since laboratory tests showed semen from this group of rams to be of the better quality. Motility as one criterion is readily observed and often used as an indica-

TABLE 2. FERTILIZATION AND LAMBING RATES OF EWES BRED DURING THE PERIOD AUGUST 22 TO SEPTEMBER 25 TO CONTROL RAMS AND TO RAMS KEPT IN THE AIR-CONDITIONED ROOM

	Ewe group							
	Slaughter				Control			
Ram group	No. of ewes	No. of C.L.	No. ova recovered	% ova fertilized	No. of ewes	No. ewes lambed	No. of lambs	% ewes lambed
Control								
Ram 3	10	19	18	27.7	10	1	1	10.0
Ram 5	10	18	16	31.2	10	3	3	30.0
Ram 6	10	17	16	18.7	10	0	0	0.0
Total	30	54	50	26.0	30	4	4	13.3
Air-conditioned								
Ram 7	10	20	19	52.6	10	4	4	40.0
Ram 8	10	17	17	82.4	10	8	12	80.0
Ram 9	10	20	17	58.8	10	3	4	30.0
Total	30	57	53	64.2**	30	15	20	50.0**

** Difference between ram groups significant at the 1% level.

tor of the quality of semen. Table 3 shows the average motility of semen from each ram used in breeding the 20 ewes. Ram no. 6 produced the lowest percent of motile cells and fertilized the lowest percent of ova, while Ram no. 8 had the highest motility rating and fertilized the highest percent of ova (table 2).

The difference in the percentage of ova fertilized by the semen from the two groups can be attributed to the effect of environmental temperature on the rams. Since an attempt was made to hold visible light and nutrition the same for the two groups of rams, it is believed that these two factors are not responsible for the differences in semen quality and fertility during this period of the year.

Lambing Rate

Lambing rates in the unslaughtered or control ewes in this study are the result of breeding at one heat period only. Control ewes that

had returned to heat were considered not pregnant and none lambed to the experimental breeding. Of the 30 control ewes bred to control rams, only four, or 13.3%, lambed. Of the 30 ewes bred to the rams in the air-conditioned room, 15 of them, or 50% lambed. The difference in percentage was highly significant when tested by Chi-square.

The percentage of bred ewes that eventually lamb is determined by the percentage of ova fertilized and embryonic death loss in the ewes. All ewes in the slaughter group had ovulated, and there is no reason to

TABLE 3. PERCENT MOTILE SPERM CELLS AND ESTIMATED EMBRYONIC DEATH LOSS IN EWES BRED TO CONTROL RAMS AND TO RAMS KEPT IN THE AIR-CONDITIONED ROOM

Ram group	Average percent motile sperm cells	Slaughter ewes No. ova fertilized	Control ewes No. lambs born	Estimated embryonic death loss	
				Fert. ova minus lambs born	Percent
Control					
Ram 3	45±5.2	5	1	4	80.0
Ram 5	43±4.9	5	3	2	40.0
Ram 6	39±4.6	3	0	3	100.0
Total	42.3±2.8	13	4	9	69.2
Air-conditioned					
Ram 7	64±1.4	10	4	6	60.0
Ram 8	75±1.7	14	12	2	14.3
Ram 9	72±1.4	10	4	6	60.0
Total	70.6±1.3**	34	20	14	41.2

** Difference in percent motile sperm cells significant at 1% level.

suspect that any of the control ewes had failed to ovulate. The low lambing rate observed in the ewes bred to the control rams was due to failure of fertility and subsequent death of the embryos.

Embryonic Death Loss

An estimate of embryonic death loss is calculated by subtracting the number of lambs born to the control ewes from the number of fertilized ova recovered from the slaughtered ewes which were bred to each ram. Each ram was bred to an equal number of control and slaughter ewes. Thus, estimated percent embryonic death loss $= \frac{\text{Fertilized ova} - \text{lambs born}}{\text{Fertilized ova}} \times 100$. In this estimate any cleaved ovum that failed to develop would be included as embryonic death.

The embryonic death loss in ewes bred to the control rams is estimated to be 69.2% and in ewes bred to the air-conditioned rams, 41.2% (table 3). This difference is not statistically significant. Of interest is the variation in the embryonic death loss among the rams. Ram no. 6 produced the lowest percent of motile cells and the highest embryonic death loss, while ram no. 8 producing the highest percent of motile cells showed the lowest embryonic death loss. These differences may be due to random variation and not to any effect of semen quality on survival of the embryo. However, the large variation among rams in estimated embryonic death loss would lead one to suspect that sperm cells may have some effect on embryo survival. Salisbury and Bratton (1951) reported higher apparent embryonic death loss between 1 and 5 months among cows bred to bulls of low fertility than among cows bred to bulls of high fertility.

The estimated embryonic death loss in ewes bred with semen from both groups of rams is rather high. Assuming that the difference in embryo loss in ewes bred to the two groups of rams is due only to sampling error, then by combining both groups of ewes the average loss of embryos for all ewes bred was 48.0%. Since embryonic death is usually thought to result from unfavorable uterine environment, it may be that this high embryo loss is at least in part due to unfavorable uterine environment early in the sexual season of ewes. Dutt (1954) in a study of ewes bred early in the breeding season reported the estimated embryonic death loss to be rather high and an important factor contributing to the low conception rate in ewes bred at this season of the year. Knowledge of embryo loss in ewes bred at periods other than early in the breeding season appears to be lacking. In view of the high loss of embryos found in ewes bred early in the season, it seems important to determine the incidence of embryo loss in ewes bred at different periods throughout the breeding season.

Summary

There was no significant difference in volume of semen produced by purebred Southdown rams kept in an air-conditioned room at 45–48° F. during the summer months when compared with rams kept at uncontrolled environmental conditions. From August 20 to September 24 the average motility rating for weekly collections was 70.3% motile cells for treated rams (air conditioned room) and 41.8% for control rams. For the same period, semen from treated rams contained 6.4% morphologically abnormal cells and the control rams 36.9%. Both of

these differences were highly significant. The treated rams also had a significantly higher sperm cell concentration (3.4 vs. 2.4 million cells per mm^3); their average rectal temperature and pulse rate also was significantly lower.

Fifty ova were recovered from 30 ewes which were slaughtered after being bred early in the breeding season with semen from the control rams, and 26.0% of the ova were cleaved. Of 53 ova recovered from 30 ewes bred by the treated rams 64.2% were cleaved. Lambing percentages of similar groups of ewes not slaughtered were 13.3% and 50.0% for the control and treated rams, respectively. The differences between the ram groups in percent of ova fertilized and in percent of ewes lambing were both highly significant.

Estimated embryonic death loss was higher (not significant) in ewes bred to control rams. Embryonic death rate was calculated to be 69.2% and 41.2% for ewes bred to control and treated rams, respectively. Estimated percentage of embryonic death loss in ewes bred to individual rams ranged from 14.3 to 100, with an over-all estimated embryonic loss of 48.0%.

These results indicate that summer temperatures are partly responsible for poor conception rate of ewes bred to Southdown rams early in the breeding season. They also point out the possibility of improving conception rate early in the breeding season by keeping rams at lower environmental temperatures during the summer months.

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THE EFFECT OF VARIATIONS IN AMBIENT TEMPERATURE AND HUMIDITY ON RECTAL AND TESTIS TEMPERATURES OF SHEARED AND UNSHEARED RAMS [1]

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INCREASED testis temperature causes seminal degeneration (Moore, 1924; Phillips and McKenzie, 1934), and high ambient temperatures have been associated with lower male fertility (Gunn *et al.*, 1942; Hulet *et al.*, 1956). The lowered fertility from increased ambient temperature, however, may not be a result of as extreme a condition as marked seminal degeneration (El Sheikh and Casida, 1955).

The testis temperature of the ram is lower than the body temperature (Phillips and McKenzie, 1934; Harrison and Weiner, 1948). It would appear, however, that the temperature of the testis might be affected more by increase in ambient temperature, such as occurs in hot summer weather, than is body temperature (Moule and Knapp, 1950). El Sheikh (1955) demonstrated that variations in ambient temperature and humidity due to the weather together with the sheared or unsheared condition of the animal interacted to produce important changes in the body temperature of rams.

The purpose of this study was to determine the effects of different levels of ambient temperature and humidity on the testis and rectal temperatures of sheared and unsheared rams.

Materials and Methods

Five sheared and five unsheared rams (carrying approximately 1 and 6 month's growth of wool respectively) of mixed breeding were exposed to both high and low relative humidities at 70, 82 and 95° F. ambient temperature for 48-hour periods. (The exposure period in the case of high humidity at 95° was restricted to 24 hours because of marked discomfort of the rams.)

Rectal and intratesticular temperatures were taken at the end of the exposure periods. The rectal temperature was taken with a clinical thermometer and the internal temperature of the testis was obtained

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by use of a needle, containing a thermocouple, inserted from the caudal position into the center of the right testicle. The thermocouple was attached to a potentiometer from which the temperature was read directly. Antiseptic procedures were followed in taking the testis temperatures.

During the experiment the rams were confined in a deeply bedded pen in the middle of a large room to prevent their seeking possible lower temperatures of floor or walls. The various temperatures of the room were attained by use of thermostatically controlled air-conditioning units, when the desired temperature was lower than that of the local weather, and by use of forced, warm air controlled by a thermostat located in the pen approximately 4 feet above the floor when the local weather was cooler than desired. The only air circulation during the experiment was from the forced air, and this, although not great in amount, unfortunately occurred only at the higher temperatures.

The experiment was begun on September 29 and completed without interruption on October 10. The sequence of the temperature exposure periods was at random except that one period of high humidity and one of low humidity was sought for each temperature. These differences in humidity were dependent upon changes in the weather. Ambient temperature and humidity were computed from dry and wet bulb thermometer readings. The sequence of exposure periods (average ambient temperature and relative humidity for each) were as follows: (1) 95° and low humidity (57%), (2) 82° and high humidity (88%), (3) 70° and high humidity (86%), (4) 95° and high humidity (78%), (5) 82° and low humidity (69%), and (6) 70° and low humidity (69%).

The assumptions made in the statistical treatment of these data were that ambient temperature, internal temperatures (rectal or testis), shearing, and humidity were fixed variables and that rams-within-shearing-group was a random variable.

Results

Rectal Temperature

Rectal temperatures (table 1) differed for 70, 82 and 95° ambient temperature when averaged over both sheared and unsheared rams and both humidity levels; they were 102.36, 102.91 and 104.50°, respectively ($P<0.01$, table 2). The over-all averages for high and low humidity also differed, 103.48 *vs.* 103.03° ($P<0.01$, table 2). There

TABLE 1. MEAN TESTIS AND RECTAL TEMPERATURES

Group	Temp.	Ambient temperature: 70° Humidity Low (69%)	70° Humidity High (86%)	82° Humidity Low (69%)	82° Humidity High (88%)	95° Humidity Low (57%)	95° Humidity High (78%)	All temp. humidity Low	All temp. humidity High	Over-all av.
Unsheared	Rectal	102.48	102.96	103.10	103.48	104.36	105.36	103.31	103.93	103.62
	Testis	95.40	96.48	95.66	97.20	98.88	100.80	96.65	98.16	97.40
Sheared	Rectal	102.02	101.98	102.34	102.72	103.88	104.42	102.75	103.04	102.90
	Testis	95.52	94.42	94.08	94.50	96.66	98.72	95.42	95.88	95.65
Unsheared and sheared	Rectal	102.25	102.47	102.72	103.10	104.12	104.89	103.03	103.48	
	High & low humidity	102.36		102.91		104.50		103.26		
	Testis	95.46	95.45	94.87	95.85	97.77	99.76	96.04	97.02	
	High & low humidity	95.46		95.36		98.76		96.53		

was a suggestion, however (P≅0.08, table 2), that the effect of humidity was not uniform at the different ambient temperatures. The difference at 70° was 0.22°; at 82° it was 0.38°, and at 95° it was 0.77°.

The over-all average temperature of the unsheared rams was 103.62° while that for the sheared rams was 102.90° (P≅0.08, table 2).

The design of the experiment did not give as good a test for the effect of shearing as it did for the effect of differences in ambient temperature and humidity. The same group of rams could not be both sheared and unsheared whereas each ram was subjected to all different levels of ambient temperature and humidity.

TABLE 2. ANALYSIS OF VARIANCE FOR TESTIS AND RECTAL TEMPERATURES (FACTORIAL DESIGN)

Source	d.f.	Mean square		F values		Error term
		BT	TT	BT	TT	
(a) Shearing (S)	1	8.00	46.1	4.10*	11.97**	(d)
(b) Ambient temp. (AT)	2	24.82	75.2	138.89**	144.6**	(i)
(c) Humidity (H)	1	3.13	14.6	24.08**	14.6**	(j)
(d) Rams/Shearing (R/S)	8	1.95	3.85			
(e) S×AT	2	0.005	2.29	0.28	4.40*	(l)
(f) S×H	1	0.40	4.15	3.08	4.15*	(j)
(g) AT×H	2	0.40	5.00	2.67*	9.26**	(k)
(h) S×AT×H	2	0.10	1.71	0.67	3.17*	(k)
(i) AT×R/S	16	0.18	0.52			
(j) H×R/S	8	0.13	1.0			
(k) AT×H×R/S	16	0.15	0.54			

* (.05<P<.10).
* (P<.05).
** (P<.01).

Testis Temperature

Humidity, ambient temperature and shearing each had a high significant effect (table 2) in changing the testis temperature. The over-all average temperatures were 96.04 and 97.02° for low and high humidity, 95.65 and 97.40° for sheared and unsheared rams, and 95.46, 95.36 and 98.76° for 70, 82, and 95° ambient temperature, respectively (table 1).

The interaction between shearing and ambient temperature can be seen by subtracting the mean of the two humidities for the sheared rams from the comparable mean of the unsheared rams at each of the ambient temperature levels. At 70° there was a difference of 0.97° between the two groups of rams but at 82 and 95° there were differences of 2.14 and 2.15°, respectively (P<.01, table 2). The interaction of shearing and humidity (P≅0.08, table 2) can be seen by comparing the difference between sheared and unsheared rams at low (1.23°) and high (2.28°) humidity. Also the temperatures of the sheared and unsheared

rams at 70° and low humidity were very similar (95.52 *vs.* 95.40°) whereas in all other instances the sheared rams had a lower testis temperature than the unsheared (S × AT × H, P≅0.08, table 2). These interactions reflect the interference of wool in the maintenance of a constant testicular temperature in relation to increasing humidity or ambient temperature.

The differences between the testis temperature for low and high humidity at 70, 82, and 95° ambient temperature are 0.01, 0.98 and 1.99°, respectively (AT × H, P<0.01, table 2). The higher the ambient temperature the greater was the effect of the higher humidity.

TABLE 3. MEAN CHANGE IN TESTIS AND RECTAL TEMPERATURES DUE TO CHANGE IN AMBIENT TEMPERATURE FROM 70–95° F.

Humidity	Temp.	Unsheared rams	Sheared rams	Both
High	Rectal	2.40	2.44	2.42
	Testis	4.32	4.30	4.31
Low	Rectal	1.88	1.86	1.87
	Testis	3.48	1.14	2.31
Both	Rectal	2.14	2.15	2.14
	Testis	3.90	2.72	3.31

Effect of Change in Ambient Temperature from 70 to 95°

The results reported thus far have shown the importance of ambient temperature in increasing both rectal and testis temperatures. To show the magnitude of this effect as well as interactions with shearing and humidity the changes in rectal and testis temperatures due to increase in ambient temperature from 70 to 95° were calculated for each ram.

Analysis of variance showed that the change in testis temperature averaged over all rams and all humidities, brought about by this change in ambient temperature, was greater than the change in rectal temperature, 3.31 *vs.* 2.14°, table 3 (P<0.01, table 4).

The changes in rectal temperature of the sheared and unsheared rams due to increase from 70–95° ambient temperature were similar for low (1.86 *vs.* 1.88°) and for high (2.44 *vs.* 2.40°) humidity, table 3. The change in the testis temperature of the sheared rams, however, at low humidity (1.14°) was less than for the unsheared rams at the same humidity (3.48°), while at the high humidity the increase in testicular temperature of the sheared rams was comparable to that of the unsheared rams, 4.30 *vs.* 4.32° (IT × S × H, P<0.05, table 4).

This indicates that shearing has little or no effect on the magnitude

of the rise in rectal temperature. Also, shearing is more effective in preventing a rise in testis temperature when humidity is low than when humidity is high.

A change from high to low humidity caused a greater change in testis temperature, 4.31 *vs.* 2.31°, than for rectal temperature, 2.42 *vs.* 1.87°, table 3 (H × IT, $P<0.05$, table 4).

While shearing had no demonstrable effect on change in rectal temperature as measured from the 70 to 95° ambient temperature change (unsheared 2.14, sheared 2.15°) the testis temperature change of the unsheared rams tended to be greater than the sheared rams, 3.90 *vs.* 2.72°, table 3 (S × IT, $P\cong0.09$, table 4).

TABLE 4. ANALYSIS OF VARIANCE FOR CHANGES IN TESTIS AND RECTAL TEMPERATURE DUE TO CHANGES IN AMBIENT TEMPERATURE FROM 70–95° F. (FACTORIAL DESIGN)

Source	d.f.	Mean square	F	Error term
(a) Internal temp.[x] (IT)	1	13.57	14.61**	(h)
(b) Shearing (S)	1	3.42	4.91[a]	(d)
(c) Humidity (H)	1	16.26	15.37**	(i)
(d) Rams/Shearing (R/S)	8	0.696		
(e) IT×S	1	3.54	3.81[a]	(h)
(f) IT×H	1	5.31	11.19*	(k)
(g) S×H	1	3.54	3.34	(i)
(h) IT×R/S	8	0.929		
(i) H×R/S	8	1.058		
(j) IT×S×H	1	3.14	6.61*	(k)
(k) IT×H×R/S	8	0.475		

[a] (.05<P<.10).
* (P<.05).
** (P<.01).
[x] Rectal vs. testicular temperature.

Summary

The effect of three levels of ambient temperature (70, 82, 95°) and high (78–88%) and low (57–69%) humidity on rectal and intratesticular temperature was studied in five sheared and five unsheared rams of mixed breeding.

Highly significant differences in rectal temperatures were shown for the different levels of ambient temperature (70, 102.36; 82, 102.91; 95, 104.50°) and humidity (103.48 high *vs.* 103.03° low) with some indication of an interaction between them ($P\cong0.08$). Rectal temperatures for sheared and unsheared rams were 102.89 and 103.62° ($P\cong0.08$).

Testis temperatures of 95.46, 95.36, and 98.76° due to 70, 82 and 95° ambient temperature; 96.04 and 97.02° due to low and high humidity; and 95.65 and 97.40° for sheared and unsheared rams showed differences which were highly significant. Interactions were indicated between shearing and ambient temperature ($P<0.01$), shearing and humidity ($P\cong0.08$), ambient temperature and humidity ($P<0.01$), and between all three variables ($P\cong0.08$).

An increase from 70–95° ambient temperature caused a greater change in testis than rectal temperatures (3.31 *vs.* 2.14°, $P<0.01$). Interactions of the sites of these internal temperatures (testis and rectal) with humidity and shearing showed similar results when taken independently ($P<0.05$, and $P\cong0.09$, respectively). The site of internal temperature also interacted significantly with these two factors when taken jointly ($P<0.05$).

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THE INFLUENCE OF EXOGENOUS PROGESTERONE ON FOLLICULAR DEVELOPMENT AND PITUITARY HORMONAL CONTENT OF BEEF HEIFERS[1]

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THE assumption is often accepted that progesterone inhibits the output of pituitary gonadotropins and by this means enforces the minimal follicular growth found during the luteal phase of the estrous cycle or during pregnancy. In cattle, however, a direct inhibitory effect of progesterone on the ovary is suggested since the amount of gonadotropin necessary to induce ovulation in the presence of an existing corpus luteum is greater than that necessary at other stages of the estrous cycle (Hammond, 1944). One approach to this problem is considered in the present study by determining the hypophyseal hormonal content in beef heifers injected with sufficient progesterone to inhibit follicular development and estrous activity.

Evans *et al.* (1933) reported that the anterior pituitary of beef animals is a poor source of gonad stimulating hormone. West and Fevold (1940) found that beef pituitaries were relatively low in follicle stimulating and interstitial stimulating activity as compared to swine. Specific assays for FSH and ICSH stimulating content of the anterior pituitaries of beef heifers were used in the present study in order to establish the ratios of these activities.

Methods and Procedures

Fourteen Hereford heifers, 24–26 months of age, had been checked twice daily with vasectomized bulls for at least 5 months prior to the trial and all of the heifers had shown at least six periods of estrus with cycle lengths between 17–24 days. They were divided at random into two groups. The first group receiving no treatment, was autopsied on the 16–18th day of their estrous cycles and compared to the treated group receiving a single injection of 1120 mg. of progesterone suspension on the 11th day of their estrous cycles, and autopsied 6–7 days after the

[1] This paper is part of a thesis submitted by the senior author in partial fulfillment of the requirements for the degree of Doctor of Philosophy in comparative physiology. Present address: Dept. of Physiology and Pharmacology, Michigan State University. Acknowledgement is made to Dr. Miriam Simpson, Dept. of Anatomy, School of Medicine, University of California, for assistance in acquiring histological assay techniques.

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progesterone injection. The follicular development and endocrine relationships of these groups should be comparable if the exogenous progesterone exerts no influence.

The progesterone suspension was prepared by grinding crystalline progesterone with a 0.3% starch emulsion in a hand homogenizer to a final concentration of 70 mg. of progesterone per cc. This preparation (1120 mg.) was injected subcutaneously in the shoulder region. It has been demonstrated (Nellor and Cole, 1956) that 560 mg. of this suspension will inhibit estrus and ovulation in beef heifers for at least 15 days following injection, regardless of the stage of the estrous cycle when treatment was given.

The ovaries of the treated and control heifers were compared macroscopically and histologically in order to test the effect of exogenous progesterone on follicular development.

The following procedures were employed to study the effect of exogenous progesterone on the pituitary hormone content of the treated heifers. The whole pituitary was removed from treated and control heifers at autopsy, and immediately stored in dry ice. Upon partial thawing the anterior lobes were separated, lyophilized and stored in an air tight container with $CaCl_2$. The glands were ground to a fine powder with mortar and pestle and taken up in sterile saline shortly before assays began. The glands were assayed for follicle stimulating (FSH), interstitial stimulating (ICSH), thyroid stimulating (TSH) and growth hormone (GH) activity. Immature female rats (Long-Evans strain) were hypophysectomized at 21 days of age, and, 14–15 days postoperative, injected subcutaneously in the abdominal region for 3 days with the preparation to be tested and autopsied on the following day. The rat ovaries and thyroids were removed, fixed in Bouin's fluid, embedded in paraffin and sectioned at 10 micra. The sections were stained with Harris haematoxylin-eosin. The tibias were freed of tissue and stored in 10% formalin.

The histological responses for FSH and ICSH, as described by Evans *et al.* (1939) were used for the assay of FSH and ICSH activity. The minimal effective dose (MED) for FSH activity is that amount of anterior pituitary required to cause an increase in size of the follicles with the beginning of antrum formation in two of three hypophysectomized female rats. The MED for interstitial stimulating activity was the amount of anterior pituitary necessary to cause partial repair of the interstitial tissue in two of three hypophysectomized female rats; i.e., the resumption of the normal nuclear pattern with some increase in

cytoplasm. The thyroid stimulating activity was measured in arbitrary units. A "—" response corresponded to a thyroid of a nontreated hypophysectomized female rat 14–15 days postoperative, a gland with abundant staining colloid, pycnotic nuclei flattened against the interfollicular connective tissue and the cells lining the lumen of the follicle exceedingly poor in cytoplasm. A "+" response defines the MED necessary to return the nuclear pattern to normal, the cells lining the follicle remain squamous and little cytoplasm is evident. In the "1" response the nuclei are well rounded with lighter staining chromatin, the cell type is low cuboidal and the cytoplasm extends only slightly beyond the diameter of the nucleus. The "1+", "2" and "2+" responses exceed that found in the normal rat, the follicular cells increasing in height to a columnar type and the colloid not being as abundant and as deep staining as in the "1" response, the differences in these values only being in the amount of cellular hypertrophy.

The growth promoting activity was assayed as proposed by Evans *et al.* (1943) by measuring the width of the uncalcified portion of the proximal tibia. It should be emphasized that these multiple assays were run on each rat injected with the anterior pituitary preparation to be tested.

Results and Discussion

The Influence of Exogenous Progesterone on Follicular Development

Macroscopic comparison of the ovaries from control heifers and from heifers that had been under the influence of exogenous progesterone for 6–7 days (table 1) indicates a definite inhibition of follicular growth in the progesterone treated group. The average follicular size in the control heifers, when only the largest follicle in the ovary was considered, was almost twice that found in the treated group (1.4 to .73 cm.). The two largest follicles (1 cm.) in the treated group were filled with blood at autopsy.

Histological sections of the ovaries of the treated heifers showed atresia of the largest follicle to be occurring in all cases except one. The granulosa layer in those follicles was reduced to a single cell layer and the theca cells surrounding the follicle were poorly developed, a common picture in follicular atresia in the cow. The one exception was in the hemorrhagic follicle of heifer 17 where a well-developed granulosa layer (10–15 cells in height) was surrounded by a thick, normal appearing thecal layer. The largest follicles in the ovaries of the control

heifers had a well developed granulosa layer surrounded by a thick zone of theca cells, except in heifer 15 where follicular atresia was present.

The Influence of Exogenous Progesterone on the Hormonal Content of the Anterior Pituitary

The results of the assays for FSH, ICSH and TSH activity are summarized for the control and progesterone treated heifers in tables 2 and 3

TABLE 1. THE INFLUENCE OF PROGESTERONE IMPLANTS ON FOLLICULAR DEVELOPMENT

Heifer no.	Dosage	Day of cycle injected	Day of cycle slaughtered	Largest follicle present in either ovary
	mg.			cm.
9	None		16	1.8
15	None		17	1.0
10	None		18	1.5
3	None		17	1.5
13	None		17	1.2
8	None		18	1.6
6	None		17	0.9
				(Av. follicle size: 1.4 cm.)
17	1120	11	17	1.0 and .7[a]
2	1120	11	17	0.8
20	1120	11	17	0.4
16	1120	11	18	0.85
14	1120	11	17	0.8
1	1120	11	18	0.8
12	1120	11	17	1.0 and 0.8[a]
				(Av. follicle size: .7 cm.)

[a] The 1.0 cm. follicle hemorrhagic in each case.

respectively. This allows determination of the MED of lyophilized anterior pituitary injected into 14–15 day post-operative hypophysectomized rats for each of the responses tested.

The MED for FSH activity is 9 mg. of lyophilized anterior pituitary gland for both the control and progesterone treated heifers. The MED for ICSH activity is 1.5 mg. of lyophilized anterior pituitary gland from both the control and treated heifers. Exogenous progesterone, although capable of inhibiting follicular growth, did not influence the pituitary FSH and ICSH content within the limits of the assay.

TABLE 2. ASSAY OF ANTERIOR PITUITARY GLANDS OF CONTROL HEIFERS

Heifer no.	9	15	10	3	13	8	6
Autopsy (Day of cycle)	16	16	18	17	17	18	17
			FSH assay				
Total dosage, mg.[a]							
30	+	+	+	+	+	+	+
15	+	+	+				
9				+	−	−	+
6	−	−	−				
3	−	−	−				
1.5		−	−	−	−		−
.3				−	−	−	−
			ICSH assay				
Total dosage, mg.							
30	+	+	+	+	+	+	+
15	+	+	+				
9				+	+	+	+
6	+	+	+				
3	+	+	+				
1.5		+	−	+	+		+
.3				−	−	−	−
			TSH assay				
Total dosage, mg.							
30	2	1+	1+	1+	2	2	2+
15	1+	1	1+				
9				1+	1+	1	1+
6	1+	1	1				
3	1	+	+				
1.5		+	−	+	+		1
.3				+	−	−	+

[a] Total dosage, the total mg. given in 3 daily injections, the rats being autopsied on the 4th day.

An MED for TSH activity could not be determined with the dose administered to the assay animals. Even at the lowest dosage injected (0.3 mg.) some of the hypophysectomized rats showed a partial repair of the thyroid follicle. This would preclude an establishment of a MED for thyroid stimulating activity. A consideration of the responses obtained, however, from the glands of the control and treated heifers indicates that there is no difference in TSH activity over the dosage range tested.

The control hypophysectomized rats had an average tibia cartilage width of 170.9 micra with a range of 152–182 micra. The readings were measured in micrometer units, one micrometer unit being equal to 17.3

micra. It was found that 1.5 mg. of lyophilized anterior pituitary gland from either control or treated heifers gave at least 50 micra increase in cartilage width over the control hypophysectomized animals. This amount is considered as statistically different in the assay for growth hormone (Greenspan *et al.*, 1949). The regression coefficients of response on dosage were estimated separately for the pituitary glands of control and treated animals. There were no significant differences in the measurements, their average being 2.6 micra. This regression coefficient was then used to adjust the data to a constant dosage level of 30 mg. of lyophilized anterior pituitary gland. The average response for treated

TABLE 3. ASSAY OF ANTERIOR PITUITARY GLANDS OF TREATED HEIFERS [a]

Heifer no.	17	2	20	16	14	1	12
Autopsy (Day) of cycle)	17	17	17	18	17	18	17
			FSH assay				
Total dosage, mg.[b]							
30	+	+	+	+	+	+	+
15	+	+	+				
9				+	+	−	−
6	−	−	−				
3	−	−	−				
1.5		−	−	−	−	−	−
.3				−	−	−	−
			ICSH assay				
Total dosage, mg.							
30	+	+	+	+	+	+	+
15	+	+	+				
9				+	+	+	+
6	+	+	+				
3	+	+	+				
1.5		+	+	+	+	−	+
.3				−	−	−	−
			TSH assay				
Total dosage, mg.							
30	2	1+	1+	1+	1+	2+	1+
15	1+	1	1				
9				1	1	1	1+
6	1+	1	1				
3	1	1	1				
1.5		+	+	1	1	1	+
.3				−	+	+	+

[a] Injected with 1120 mg. of progesterone suspension on day–11 of the cycle and autopsied 6 or 7 days later.

[b] Total dosage, the total mg. given in 3 daily injections, the rats being autopsied on the 4th day.

and control heifers turned out to be statistically non-significant, the average adjusted response for the control heifers being 332.5 micra as compared to 332.4 micra for the treated group. On the basis of this analysis there was no difference in the anterior pituitary content of GH promoting activity in progesterone treated and control heifers.

The results of these assays are in agreement with various reports (Evans *et al.*, 1933; Hammond, 1950) indicating that the pituitary content of cattle is higher in luteinizing than follicle stimulating activity. The determination of the MED for these activities also establishes their relative potencies. The MED for ICSH activity was 1.5 mg. of lyophilized anterior pituitary as compared to the MED for FSH activity of 9 mg. of lypophilized anterior lobe. This represents a 6 to 1 ICSH:FSH activity ratio.

On the basis of these assays it can be postulated that either exogenous progesterone exerts its inhibitory influence on extra-pituitary sites, or that pituitary hormonal content is a poor index of secretory activity.

Summary

The pituitary hormonal content in seven heifers treated with 1120 mg. of progesterone 6 days before slaughter was compared to that of seven control heifers. Exogenous progesterone in amounts capable of inhibiting estrus and ovulation had no detectable effect on the hormonal content of the anterior pituitary of beef heifers regarding FSH, ICSH, TSH and GH stimulating activity.

The ratio of ICSH:FSH activity of beef heifer anterior pituitary is 6:1.

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EFFECT OF CORN SILAGE ON THE GROWTH, REPRODUCTIVE DEVELOPMENT AND SEMEN PRODUCTION OF YOUNG DAIRY BULLS[1]

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INVESTIGATORS have shown that grass silage may be fed to mature dairy bulls in moderate to large quantities without impairing the libido of the bull or the quality and quantity of semen produced (Flipse *et al.*, 1952; Quicke *et al.*, 1950). Recent reports (Porter and Kesler, 1954; Sykes *et al.*, 1955) indicate the interest in feeding grass silage to the dairy calf during early life. Corn silage has been tested in the diet of the calf (Converse and Wiseman, 1952; White and Kuelling, 1919) but the results have not provided conclusive evidence that corn silage should or should not be used for young calves.

The present investigation was undertaken to determine the effects of feeding corn silage starting at 12 weeks of age on the growth and sexual development of bull calves and on the quality and quantity of semen produced by them.

Experimental

Four sets of identical twin bulls were used in this study. Monozygosity was determined by similarity of phenotypes and verified by blood typing. One set of Guernsey twins was started on the experiment in February 1952. Two additional sets of Guernseys and one set of Jersey-Shorthorn crossbreds were started in March, July, and December 1953, respectively. Twins were obtained from Pennsylvania farms at 4 to 10 weeks of age and were maintained on a standard limited milk feeding program until placed on the experiment at 12 weeks of age. The experiment covered the period of the 13th to the 112th week inclusive.

One member of each pair of twins was maintained on a control ration of hay and concentrate. The other member of the pair received the experimental ration of hay and corn silage plus a limited amount of concentrate mix. Hay was fed to both groups at the rate of one lb. daily per 100 lb. of body weight, second cutting clover being fed to 48 weeks of age and a timothy-clover mixture thereafter.

The twins were fed at a level calculated to meet the National

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Research Council recommended allowance for total digestible nutrients (Loosli *et al.*, 1950). The control bulls received about 3 lb. of concentrate mix daily at 12 weeks, and this was gradually increased to a maximum of about 8 lb. daily. Experimental bulls were offered corn silage at the rate of 3.5 lb. daily per 100 lb. of body weight, plus whatever concentrate mix was required to maintain the recommended allowance for TDN. During the first week or two, while the animals were becoming accustomed to silage, the ration of concentrate mix approached 3 lb. daily. It was gradually reduced and three of the four experimental bulls received no concentrate after 52 weeks of age. The first twin placed on silage did not eat silage readily; consequently, to maintain the desired nutrient consumption it was necessary to increase concentrate consumption to a maximum of 4.6 lb. daily. This bull received some grain until the 79th week of age.

Corn silage harvested in 1951 through 1954 was used in this trial. Only one silo was available for corn silage; thus corn silage was not available for 11 weeks in the summer of 1954 and for 4 weeks in the summer of 1955. Red clover-timothy silage preserved with sodium metabisulfite replaced the corn silage during these periods. Three sets of twins were involved in 1954 and one set in 1955. The silage was of only fair quality as a result of dry weather during the growing seasons. Samples of the silage as fed were analyzed monthly; the average dry matter content was 28.2% and the average crude protein content was 2.2%. The clover hay averaged 13.9% protein and the timothy-clover hay averaged 9.1%. The concentrate mixture contained the following ingredients in percent: ground corn, 28; crushed oats, 30; wheat bran, 30; soybean oil meal, 10; salt, 1; and mineral mix, 1. It was calculated to contain 73% TDN and 16% crude protein.

Approaching sexual maturity was detected by using a heifer of appropriate size as a teaser, starting at 24 weeks of age (Flipse *et al.*, 1953). Sexual maturity was recorded as the age at which the first ejaculate containing motile spermatozoa was obtained. One semen sample was collected from each bull biweekly through the 72nd week, weekly from 73 to 96 weeks, and semiweekly from 97 to 112 weeks. Semen quality and quantity tests were performed on each ejaculate and included volume of ejaculate, number of spermatozoa per milliliter, percent of spermatozoa initially motile, percent of unstained (live) spermatozoa, and the percent of motile spermatozoa after 5, 10, and 15 days of storage at 5° C. Procedures for these tests have been reported previously (Flipse *et al.*, 1953).

Blood samples were obtained at 12-week intervals from 12 to 72 weeks of age and were analyzed for hemoglobin, total plasma protein, nonprotein nitrogen, urea, glucose, calcium, phosphorus, and carotene. Statistical treatment of the data was by analysis of variance, as described by Snedecor (1946).

Results and Discussion

Consumption of the concentrate mixture, hay, and silage is shown in table 1. Although one of the calves apparently did not relish silage, at

TABLE 1. AVERAGE FEED AND NUTRIENT CONSUMPTION PER BULL

Group	Daily consumption during the age period in weeks					
	13–24	25–48	49–72	73–96	97–112	13–112
			Concentrate, lb.			
Control	2.8	5.6	6.9	7.3	7.4	6.3
Silage	2.0	2.1	0.6	0.3	0	0.9
			Hay, lb.			
Control	2.2	4.1	7.2	9.6	11.2	7.1
Silage	2.2	4.1	7.2	9.6	11.1	7.1
			Silage, lb.			
Control						
Silage	5.3	13.5	24.2	30.1	34.5	22.3
			Total digestible nutrients, lb.			
Control	3.2	6.2	8.7	10.2	11.1	8.2
Silage	3.5	6.1	8.5	10.5	11.8	8.3
			Digestible protein, lb.			
Control	0.59	1.16	1.25	1.52	1.63	1.29
Silage	0.55	0.88	0.81	1.00	1.10	0.89

24 weeks of age the average daily consumption of corn silage for the silage group was 3.1 lb. per 100 lb. of body weight. Corn silage consumption undoubtedly varies with the nature of the ration, for Converse and Wiseman (1952) reported that young calves consumed very little fresh corn silage when the silage was the sole roughage and skimmilk was fed to 6 months of age.

The total digestible nutrient and digestible protein intakes shown in table 1 are based on measured consumption and chemical analyses of feedstuffs, and on the average digestion coefficients of Morrison (1948). TDN consumption was similar in the two groups, but protein

TABLE 2. AVERAGE CONCENTRATIONS OF BLOOD CONSTITUENTS

Constituent	Control group	Silage group
Hemoglobin, gm. %	11.5 (0.38)[a]	11.5 (0.45)
Total plasma proteins, gm. %	7.9 (0.15)	8.0 (0.19)
Nonprotein nitrogen, mg. %	31 (2.3)	25 (1.1)
Urea, mg. %	35 (1.5)	28 (4.4)
Glucose, mg. %	55 (3.4)	56 (1.7)
Plasma calcium, mg. %	10.3 (0.09)	10.7 (0.19)
Plasma phosphorus, mg. %	8.0 (0.26)	7.2 (0.49)
Plasma carotene, mcg. %	307 (47.0)	403 (31.1)

[a] Standard error of the mean.

intake was considerably lower in the experimental than in the control group.

Of the blood constituents shown in table 2, only nonprotein nitrogen, urea, and carotene differed noticeably between groups. Nonprotein nitrogen and urea tended to be lower in the silage-fed group (P about 0.06 and 0.15, respectively); possibly this is a reflection of the lower protein intake of this group. Plasma carotene tended to be higher (P about 0.15) in the silage-fed group, but the levels in both groups were more than adequate for normal growth and reproduction. It has been reported (Hancock, 1954) that identical twins are much less efficient in studies of certain blood constituents than in studies of growth or semen characteristics.

Growth of the animals was determined by measuring body weight weekly and height at withers, heart girth, and paunch girth every 4

TABLE 3. AVERAGE CHANGES IN BODY MEASUREMENTS

Group	Initial measurement	Change during the age period in weeks					
		13–24	25–48	49–72	73–96	97–112	13–112
				Body weight, lb.			
Control	156	109	290	300	258	164	1120 (45)[a]
Silage	157	109	283	294	224	183	1093 (53)
				Height at withers, cm.			
Control	82.9	10.2	18.6	11.5	6.9	4.2	51.5 (1.0)
Silage	83.4	10.1	17.9	11.4	6.0	4.1	49.5 (1.4)
				Heart girth, cm.			
Control	98	16	36	23	10	11	97 (1.8)
Silage	98	16	26	24	12	10	96 (1.5)
				Paunch girth, cm.			
Control	122	22	34	25	18	10	109 (4.3)
Silage	121	20	30	26	15	16	108 (2.8)

[a] Standard error of the mean.

weeks. The initial body measurements and changes during the experimental period are recorded in table 3. The control bulls tended to gain slightly more in body weight, height at withers and heart girth than did the experimental bulls, but the differences did not approach the 5% level of probability. No tendency toward paunchiness was

TABLE 4. SUMMARY OF SEMEN CHARACTERISTICS

Group	Age of bulls in weeks		
	to 72 weeks [a]	73 to 96 weeks [b]	97 to 112 weeks [c]
	Volume per ejaculate (ml.)		
Control	2.60	3.54	3.60
Silage	2.61	3.23	3.84
	Number of spermatozoa $\times 10^6$ per ml.		
Control	838	1380	1540
Silage	769	1329	1641
	Initial motility, %		
Control	57.4	61.3	61.5
Silage	55.9	61.0	60.0
	Total motile spermatozoa $\times 10^6$ per ejaculate		
Control	1598	3129	3555
Silage	1385	2693	3894
	Unstained (live) sperm, %		
Control	62.3	71.9	72.0
Silage	63.2	70.7	69.7
	Motility after 5 days storage at 5° C., %		
Control	36.9	44.9	42.3
Silage	37.3	44.7	42.2

[a] One ejaculate collected biweekly.
[b] One ejaculate collected weekly.
[c] One ejaculate collected semiweekly.

observed in either the control or experimental bulls, and no difference between groups was noted in sexual activity. The growth results are in agreement with those of Converse and Wiseman (1952), who reported normal growth with corn silage as the sole roughage. However, younger calves (birth to 16 weeks) may not respond so well to corn silage (Gotwalt and Kesler, 1956).

The feeding of corn silage apparently had no effect upon attainment

of sexual maturity, inasmuch as the average age at which the first ejaculate containing motile spermatozoa was obtained was 41 weeks (range 36–44) for the control group and 39 weeks (range 34–44) for the silage group. Average values for the various semen characteristics are presented in table 4. None of the differences in table 4 approached the 5% level of probability when tested by analysis of variance. Thus, under the conditions employed in this trial, corn silage provided an excellent source of nutrients for the growth and reproductive development of dairy bulls.

Summary

Four sets of identical twin bull calves were used in a trial comparing an experimental ration of corn silage and hay with a control ration of concentrate and hay. The twins were fed from 13 to 112 weeks of age inclusive. TDN consumption was maintained at the level recommended by the National Research Council. Digestible protein intake was lower for the bulls fed silage than for those fed concentrate.

Growth, attainment of sexual maturity, and quantity and quality of semen produced were similar in the two groups. Blood urea and non-protein nitrogen tended to be lower in the silage-fed group than in the control group, possibly as a result of the lower protein intake on the silage ration.

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FEEDLOT BLOAT STUDIES. I. ANIMAL AND DIETARY FACTORS

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TYMPANITES (bloat) of ruminants results in losses, to the livestock industry of the United States, estimated at some forty million dollars annually.[4] Although a large percentage of the losses occur on legume pastures, bloat in the feedlot can often mean the difference between profit and loss to the feeder.

During the last fifteen years, several theories have been advanced for the pathogenesis of bloat (Cole *et al.*, 1942; Jacobson *et al.*, 1942; Nichols, 1954; Weiss, 1953) and several biochemical constituents have been indicated as causative factors (Clark and Quinn, 1945; Ferguson, 1950; Ferguson *et al.*, 1949; Lindahl *et al.*, 1954, 1957; McCandlish, 1937; Olson, 1944; Quinn, 1942).

However, variations in the incidence of bloat from year to year, among seasons of the same year, among farms within a general area, and among animals on the same farm, together with lack of universal acceptance of a single theory (Dougherty, 1953; Hungate *et al.*, 1955; Johns, 1954; Lindahl *et al.*, 1956), would indicate that the pathogenesis of bloat is complex and probably results from interactions of multiple factors.

Recent fundamental work by Dougherty and Meredith (1955) and by Dougherty and Habel (1955) on the mechanism of eructation and by Dziuk and Sellers (1955, 1955a) on the vagal nerve supply to the bovine stomach, has been of utmost importance toward an understanding of the physiology of eructation. The work of Dougherty *et al.* (1955) on the physiological effects of insufflation of the stomach of sheep has also provided an insight into the physiological manifestations arising from acute bloat.

However, except for limited work reported by Hungate *et al.* (1955), a preliminary report by Jacobson and Lindahl (1955), and a recent report by Barrentine *et al.* (1956) little interest has been displayed in

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[4] Losses in Agriculture, A Preliminary Appraisal for Review, ARS, USDA, June, 1954, ARS–20–1.

the bacteriological aspects of ruminant bloat. It would appear that basic research on all phases of the bloat problem is needed before an understanding of the complexities of the pathogenesis of ruminant bloat can be obtained.

The studies reported in this and following papers were initiated in order to determine some of the factors concerned with the development of feedlot bloat, to provide material for studies on microbiology and metabolic activity of rumen microorganisms during the development of bloat, and to provide a basis for comparisons between feedlot and pasture bloat.

General Methods Employed in the Animal Studies

Shorthorn and Shorthorn × Hereford steers, heifers and mature cows were used in the studies. Intact animals were generally used in the preliminary studies, while fistulated animals were largely used in later studies. Fistulation was conducted according to the general techniques described by Dougherty (1955), one-piece stainless steel cannulas being used.

All animals were individually fed twice daily. No bedding was employed and concrete paved exercise paddocks were used. Water was offered ad lib during the first year; but in subsequent work, water was offered only at feeding time and a record of the intake obtained.

The basic diet was similar to that used by Smith *et al.* (1953) for the production of frothy bloat symptoms. The exact composition of the test diets will be discussed in relation to the various experiments.

All animals were rated for the degree of bloat displayed one hour after each feeding. Non-fistulated animals were arbitrarily rated for the degree of bloat, while direct pressure readings in mm. Hg were taken from the fistulated animals. Correlations between distention and firmness of the distention, apparent discomfort of the animals, and direct pressure readings with a fistulated animal were used as a basis for the rating scale for the non-fistulated animals. A tympanometer, built and calibrated according to the description given by Kleiber (1945) was also used for a period of time. The numerical and adjective scales with correlations between the methods of rating the degree of bloat are given in table 1. According to the scale, a rating of 1 is equivalent to approximately 10 mm. Hg, 2 to 20 mm. Hg., etc. As is shown in table 1, use of the tympanometer tended to overrate the lesser degrees of bloat. The bloat index, when employed, is a summation of the total bloat cases times the respective severity ratings. For instance, if an animal received

three ratings of 2, one rating of 3 and six ratings of 1 during a period of one week (14 rating possibilities) the total bloat index would be 6 + 3 + 6 or 15, the average daily bloat index would be 15/7 or 2.14 and the average bloat index per feeding would be 15/14 or 1.07.

TABLE 1. BLOAT RATINGS

Method of rating	Ratings				
Adjective rating	Slight		Moderate		Severe
Numerical rating	1	2	3	4	5
Equivalent in mm. Hg.	10–15	15–25	25–35	35–45	45+
Average mm. Hg.	12.5	20	30	40	
Tympanometer ratings					
Range in mm. Hg.[a]	17.0–23.0	21.0–25.9	26.0–30.0		
Average mm. Hg.	19.5	22.8	27.7		

[a] Average of 20 readings at each level.

Experimental Results

Experiment I

Preliminary Studies on Diet Composition. Six mixtures were studied to determine if substitution of barley for corn and alfalfa meal for alfalfa hay would increase the incidence of bloat over that obtained with a mixture similar to the one reported by Smith *et al.* (1953). The full-feed mixtures used in this preliminary study were: 1A, 14 lb. concentrate (78.3% ground corn, 20.7% soybean oil meal and 1% salt) and 4 lb. of number 2 alfalfa hay per animal per day; 1B, same concentrate as 1A but 4 lb. of alfalfa meal was used to replace the hay; 1C, same as 1A except that the salt contained 1 part of a sulfated mono-glyceride type household detergent to 4 parts of salt; and 2A, 2B, and 2C, which were the same as the above except that barley was substituted for the corn.

Six animals, averaging 784 lb. in weight, were changed from a diet of alfalfa hay to a full feed of the bloat diets by increasing the concentrate mixture by one lb. per day and reducing the hay by 2 lb. per day until the animals were receiving 14 lb. of concentrate and 4 lb. of hay per day. The starting concentrate was the same as was used for each animal during the first experimental period. The experiment was started after the animals were half-way on full feed, *i.e.*, after the first 7 days.

The experiment was then divided into 4 thirty-day periods, running from March 17 to July 13, 1954. During the first 90 days, one animal

received each of the corn-containing diets for each of three 30-day periods in a reversal type test and three additional animals received the barley containing diets in the same manner. During the last 30 days of the experiment all animals that had received the barley diets were put on diet 1B and all animals that had received the corn diets were put on diet 2B.

TABLE 2. COMPARISON OF DIETARY REGIMES IN THE PRODUCTION OF BLOAT

Diets	Period				Totals
	1st	2nd	3rd	4th	
A's (Hay)					
Feed consumed	981.5	958.0	984.0		2923.5 lb.
Bloat cases	1	7	43		51
Bloat index	1	9	76		86
B's (Alf. meal)					
Feed consumed	923.0	1011.0	870.5		2804.5 lb.
Bloat cases	19	28	64		111
Bloat index	30	50	131		211
C's (Hay+Detergent)					
Feed consumed	821.0	936.5	1057.0		2814.5 lb.
Bloat cases	2	24	50		76
Bloat index	4	35	116		155
Corn diets					
Feed consumed	1454.0	1434.5	1470.0	1450.0	5808.5 lb.
Bloat cases	3	35	110	139	287
Bloat index	5	59	242	280	586
Barley diets					
Feed consumed	1271.5	1471.0	1441.5	1343.0	5527.0 lb.
Bloat cases	19	24	47	138	228
Bloat index	30	35	81	405	551

A summary of the results of this experiment are given in tables 2 and 3.

Results of analysis of variance, using the bloat index and data for the first three periods, are given in table 4.

The differences between the two grains, or among the three diets (A, B, and C) were not significant. Differences between the responses obtained by using barley or corn in the three types of diets were significant at the 5% level. The highly significant increase in the incidence of bloat and its severity with time did not result from increases in total feed consumption.

TABLE 3. ANIMAL VARIATIONS AND EFFECT OF TIME ON THE INCIDENCE OF BLOAT
(Experiment I)

Animal	Period				Total
	1st	2nd	3rd	4th	
No. 18					
Diet	1B	1C	1A	2B	
Feed consumed	475.0	421.5	503.5	502.5	1902.5
Bloat cases	0	0	1	25	26
Bloat index	0	0	1	29	30
No. 22					
Diet	2A	2B	2C	1B	
Feed consumed	461.5	496.0	532.0	536.0	2025.5
Bloat cases	0	0	0	37	37
Bloat index	0	0	0	52	52
No. 24					
Diet	2C	2A	2B	1B	
Feed consumed	362.0	460.0	429.0	438.0	1689.0
Bloat cases	0	0	5	44	49
Bloat index	0	0	6	68	74
No. 20					
Diet	2B	2C	2A	1B	
Feed consumed	448.0	515.0	480.5	476.0	1919.5
Bloat cases	19	24	42	57	142
Bloat index	30	35	75	160	300
No. 27					
Diet	1C	1A	1B	2B	
Feed consumed	459.0	498.0	441.5	360.0	1758.5
Bloat cases	2	7	59	56	124
Bloat index	4	9	125	173	311
No. 26					
Diet	1A	1B	1C	2B	
Feed consumed	520.0	515.0	525.0	480.5	2040.5
Bloat cases	1	28	50	58	137
Bloat index	1	50	116	203	370
Totals					
Feed consumed	2725.5	2905.5	2911.5	2793.0	11335.5
Bloat cases	22	59	157	277	515
Bloat index	35	94	323	685	1137

Experiment II

Effect of Time on the Incidence of Bloat. As a result of the observations obtained during the first experiment, a second experiment was set up to study some of the factors associated with the increase in the incidence of bloat with time. Five animals of approximately 800 lb. body weight were used in this experiment. Previous to the experiment the animals had been on a diet composed of mixed grass hay and corn silage.

The first four animals were started on the experiment on January 28, 1955, by feeding them 5 lb. of mixed grass hay and 6 lb. of a bloat producing mixture (61% barley, 16% soybean oil meal, 22% alfalfa meal and 1% salt) for a period of 4 weeks. They were then shifted to the bloat diet within a five-day period by reducing the hay by 1 lb. per day and increasing the concentrate by 0.5 lb. per day. The rate of feeding was then increased by 0.5 lb. per day until the animals were receiving

TABLE 4. ANALYSIS OF VARIANCE EXPT. I [a]

Source of variation	d.f.	S.S.	M.S.	F.
Total	17	108.9678		
Grains (corn vs. barley)	1	3.6630	3.6630	6.15 NS [b]
Animals within grains	4	54.5300	13.6325	28.89**
Periods	2	24.4173	12.2086	20.55**
Diets (A, B and C)	2	5.8996	2.9498	4.95 NS
Grains × Periods	2	8.2342	4.1171	6.91 NS
Grain × Diets	2	9.8414	4.9207	8.26*
Error	4	2.3823	0.5956	

[a] The analysis was made by using the square root of the bloat index plus 0.5 i.e., $\sqrt{X+0.5}$, where X was the bloat index, so that 0 bloat indices could be handled.
[b] Non-significant.
* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.

14 lb. of the bloat producing diet per day. The fifth animal was started on the experiment approximately one month later. This animal was started on the same allowance of hay and bloat diet, as were the other four animals, but was changed over to a full feed of the bloat diet over an 11-day period by gradually reducing the hay and increasing the concentrate. After the animal was on the bloat diet, the rate of feeding was increased by 0.5 lb. per day until it received a total of 14 lb. of feed per day.

The results on the incidence of bloat with time are summarized by 14-day periods, in table 5. In order to fit the data to equal periods, the records for the first 3 days for the four animals and for the first 2 days for the fifth animal were omitted.

Subsequent papers will cover observations made on the physical nature of the rumen contents and data on the metabolic activity of the rumen microorganisms during the same period of time.

Analysis of variance conducted on the bloat indices, using the last seven periods for the first four animals and the first seven periods for the fifth animal, again revealed that the differences among animals and

TABLE 5. EFFECT OF TIME ON THE INCIDENCE OF BLOAT. EXPT. II

Period	1	2	3	4	5	6	7	8	
Total days	14	28	42	56	70	84	98	112	Totals
Total for first four animals									
Feed consumed, lb.									
Hay	299.0	256.0	4.0						559.0
Bloat diet	336.0	348.0	604.5	767.0	775.0	780.0	783.5	784.0	5178.0
Total feed	635.0	604.0	608.5	767.0	775.0	780.0	783.5	784.0	5737.0
Water intake, lb.	2009.0	1966.0	1774.5	2089.5	2328.0	2401.5	2451.0	2460.5	17480.0
Bloat record									
No. of cases	0	0	9	19	30	32	71	73	234
Bloat index	0	0	11	25	33	49	117	109	344
Record for fifth animal									
Feed consumed, lb.									
Hay	24.0								24.0
Bloat diet	109.0	163.0	177.5	176.5	184.5	166.5	187.0	190.0	1354.0
Total feed	133.0	163.0	177.5	176.5	184.5	166.5	187.0	190.0	1378.0
Water intake, lb.	473.5	539.5	572.0	688.5	601.5	655.5	741.5	600.5	4852.5
Bloat record									
No. of cases	2	15	16	17	13	19	24	28	134
Bloat index	5	26	33	29	14	35	38	61	241

the increase in bloat index with time were highly significant (0.01 probability level). With respect to the period differences, the linear effect was the only significant effect; quadratic, cubic, and others were not significant.

The increase in the incidence and severity of the bloat cases with time in the two experiments cannot be explained on the basis of total feed intake, or by changes in the diets as were made in experiment I, or methods of management; as the total feed intake by periods is not correlated with the bloating records, the increase occurred on all the dietary regimens studied, and the methods of management remained constant. Although the average water intake increased during the last five periods in the second experiment, this increase in water intake was coincident to an increase in the average environmental temperature. Variations among animals and for the same animal from period to period indicate that the incidence of bloat was not related to water intake.

In the first experiment, three of the six animals accounted for 78% of the bloat cases, and in the second experiment one of the first four animals accounted for 44% of the cases.

The difference among animals tended to persist throughout the experimental use of the animals. In additional studies with the same animals on the same or similar diets, the individual bloat indices have been closely correlated from one time to another.

Data collected for all animals during the course of experiments I and II showed no significant correlations between the individual bloat indices and the average daily gain, feed per lb. of gain, or feed intake in relation to body weight, of the animals. The largest correlation was between the feed intake-weight ratio and the bloat indices, where $r=0.4$.

After each of the experiments, the animals have been maintained on the bloat producing diets for additional studies. Observations made during these additional studies indicate that the incidence and severity of the bloat cases tended to plateau after the animals had received the bloat producing diets from 4 to 5 months. Also, correlations between feed intake and bloating behavior after the animals reach an equilibrium in the incidence of bloat appear to be different from those during the first 4 to 5 months that the animals receive the bloat producing diets. Observations made on animals that have received the bloat diets for long periods of time will be covered in subsequent papers.

Effect of Physical Nature of the Diet on the Incidence of Bloat

At the end of the above discussed experiments, observations were made on the substitution of part of the bloat producing diet with alfalfa hay and on the effect of pelleting the diet on the incidence of bloat.

At the end of experiment I three animals with a consistent bloating record were switched from diet 2B of 14 lb. of concentrate (78.3% barley, 20.7% soybean oil meal and 1% salt) and 4 lb. of alfalfa hay per day to a diet composed of 8 lb. of the same concentrate and 16 lb. of alfalfa hay per day. The animals were later limited to 6 lb. of concentrate and 12 lb. of alfalfa hay per day. One animal quit bloating immediately, one within 6 days and the other within 8 days. However, two to three weeks after the animals quit bloating they began to bloat again and displayed a consistent record of bloating, although no further alteration was made in the diet.

At the end of experiment II, two animals were switched from a ration of 14 lb. of the bloat producing diet (61% barley, 16% soybean meal, 1% salt, and 22% alfalfa meal) per day to a ration of 13 lb. of number 2 alfalfa hay and 6.5 lb. of the bloat producing mixture per day. The last ration was compounded to supply the same daily intake of net energy as supplied by 14 lb. of the bloat producing diet. Neither animal quit bloating during a five-week period following the switch to the high alfalfa diet.

In six cases, four animals have been completely switched over to a diet of alfalfa hay or grass hay after being on the bloat producing diet for extended periods of time. They quit bloating within 2 days and did not bloat again unless started on the bloat producing diet for a second time.

During the course of additional feedlot studies pelleting of the bloat producing diet was used for four different animals, in an attempt to increase feed consumption. The animals had been on the bloat producing diet for several months, and were all bloating regularly before being fed the pellets. Three animals responded in the expected manner, *i.e.*, feed consumption was increased and the bloat index was in turn increased. However, pelleting of the diet for a fourth animal resulted in a marked decrease in the incidence of bloat. During a 7-day period preceding pellet feeding this animal had an average daily bloat index of 3.9. The animal was then fed pellets for 10.5 days and had an average daily bloat index of 2.0. A switch back to the unpelleted diet resulted in an immediate increase in the bloat index (daily average of

4.2 for the next 15.5 days). The animal was then fed pellets for a total of 48 days; there was little change in the incidence or severity of bloat during the first 19 days, but the average daily bloat index dropped to 0.9 during the last 29 days of this period. The animal was then switched back to the unpelleted feed and maintained the low average daily bloat index of 0.8 for 6 days, but then had an average daily bloat index of 3.9 for the next 9 days and continued to display a consistent bloating record on the unpelleted diet. The pellets used were ⅜ inch in diameter, approximately ¾ inches in length, were hard, and did not break readily.

The addition of 3 lb. of ground corn cobs to 6 lb. of the bloat producing diet did not have any apparent effect on the incidence of bloat in the same animal over a 12-day period.

The results of feeding the pelleted bloat-producing diet would indicate that the reaction of different animals to the physical nature of the diet may be quite different. It is also interesting to note that the time interval required for the pellet sensitive animal to begin to bloat when it was first started on the bloat producing diet, several months previous, was considerably longer than for the other three animals.

Observations on Ruminal Motility

It is impossible to say, at the present time, that the strength of the ruminal contractions are normal in the bloating animals or that ruminal motility is not altered somewhat when the animals are switched over to the bloat producing diets; however, motility has been quite active in the bloating animals and the contractions increase in frequency as the animals begin to bloat. Repeated motility tracings on one animal have shown that the frequency of contractions definitely increases as the animal begins to bloat. A series of motility tracings taken a year apart on this animal did not indicate any apparent change in the motility pattern as a result of continued ingestion of the low-fiber diet. Furthermore, the ruminal motility pattern of this one animal does not differ in any apparent respect from the motility patterns taken in the same manner from other fistulated animals on an alfalfa hay diet.

Discussion

A highly significant difference among animals in their susceptibility to bloating has been reported by a number of investigators. (Cole *et al.*, 1942; Knapp *et al.*, 1943; Johns, 1954). The results of the experiments

reported in this paper tend to confirm the report of Johns (1954) that there is little relationship between the total feed intake by different animals and their bloat severity.

This difference among animals in regard to bloating susceptibility does not appear to arise from a simple cause. Although the tendency to bloat appears to be inherited (Knapp *et al.*, 1943; Hancock, 1953; Johns, 1954), observations by Johns (1954) revealed a significant difference between identical twins in their bloating susceptibility. It is difficult to explain the difference between identical twins on an anatomical or physiological basis.

The highly significant increase in the incidence and severity of bloat over an extended period of time, as observed in these experiments, has a number of ramifications. It is very difficult to correlate this observation with any of the single theories that have been advanced for the cause of bloat. If bloating was caused by a simple lack of coarse, fibrous material, it would appear that the incidence of bloating would reach a peak as soon as the rumen was cleared of the coarse material. Cole and Mead (Cole *et al.*, 1945) encountered only one mild case of bloat over a 7-week period from feeding a non-roughage diet to lactating cows, while Mead and Goss (1936) reported bloat on the same diet in previous experiments. Cole *et al.* (1945) concluded that: "Apparently an additional factor, ruminal atony, for example, may have been involved in the longtime experiments of Mead and Goss." Observations in the present experiments support the conclusion that an additional factor or factors apart from lack of sufficient coarse roughage is involved, but it does not appear to be rumen atony.

A lack of coarse roughage may well be a contributing factor in the pathogenesis of bloat; however, the relationship does not appear to be simple and direct. The observations on the feeding of pellets to the one animal in the present experiments would indicate that the relationship between the physical nature of the diet and the pathogenesis of bloat cannot be ignored.

The time factor in the development of feedlot bloat could lead to some serious misinterpretations of experimental data if its existence was not recognized.

The bloat encountered in these experiments was of the frothy type, although a varying amount of "free gas" was always found in the rumen. A certain amount of this gas could be released with a large sized stomach tube directed toward the dorsal blind sac of the rumen

and could always be released from a fistulated animal by slowly opening the pinch cock attached to the cannula stopper.

Summary

Experimental conditions employed at the Agricultural Research Center, Beltsville, Md., in long-term feedlot bloat studies are described, including methods used in rating the severity of bloat cases in cattle.

Experimental frothy bloat was produced in two experiments, by using a basal diet composed of 61% barley, 22% alfalfa meal, 16% soybean oil meal and 1% NaCl. No significant differences in the bloating effect of the diet was obtained by substituting corn for the barley, or alfalfa hay for the alfalfa meal.

A highly significant difference was noted among animals in their susceptibility to bloat. This difference could not be correlated with their eating habits. In both experiments there was a highly significant increase in the incidence and severity of bloat as the length of time on bloat producing diets increased. This increase in the incidence of bloat did not result from an increase in feed consumption. It is difficult to correlate the highly significant increase in the incidence and severity of bloat over an extended period of time with any of the single theories that have been advanced for the cause of bloat.

Observations made during the above experiments support the conclusion that an additional factor or factors apart from lack of sufficient coarse roughage is involved in this type of bloat. Furthermore, this factor does not appear to be rumen atony.

The bloat encountered in these experiments was of the frothy type, although a variable amount of "free" gas was always found in the rumen. A certain amount of gas could be released with a large sized stomach tube directed toward the dorsal blind sac of the rumen and could always be released from a fistulated animal by slowly opening the pinch cock attached to the cannula stopper.

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UTILIZATION OF AMMONIATED INDUSTRIAL PRODUCTS BY CATTLE

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AN important problem in the feeding of nonprotein nitrogen compounds to ruminants is the production of ammonia in the rumen at a rate greater than that of effective utilization by rumen microorganisms. Utilization of the ammonia requires, among other things, available carbohydrate; its accumulation in the rumen is undesirable and may be detrimental (Gallup *et al.*, 1953; Hale and King, 1955).

Millar (1942) and Stiles (1952) have developed methods of impregnating several agricultural products with ammonia to induce chemical combinations that may release ammonia nitrogen in the rumen at a rate near that at which complex carbohydrates are hydrolyzed and become available for protein synthesis. Evaluation of some of these products in fattening- and wintering-type rations for cattle is reported in the present paper. Because of the number of trials involved, results are presented separately for each type of ration.

Experiments with Fattening-Type Rations

Procedures

Two commercial preparations of ammoniated cane molasses (ACM), one containing 16% protein equivalent and the other 33%, and ammoniated furfural residue (AFR) containing 34.4% protein equivalent were compared with cottonseed meal as a standard protein supplement in two metabolism trials and two feed-lot trials. The composition of these ammoniated products and rations containing them, as determined by conventional feed analysis, is shown in table 1. The average composition of the other feeds used in trials and in wintering trials is generally known; the alfalfa hay and prairie hay contained 16% and 4.9% protein, respectively, the sorghum silage, 1.6% and the cottonseed meal, milo grain and corn, 39%, 11% and 8%, respectively.

Trial 1, metabolism. Nine grade Hereford yearling steers weighing

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about 550 lb. were used in a metabolism trial of a 3 × 3 latin square design with three different squares being used. Each animal was fed twice daily 454 gm. of prairie hay and 1135 gm. of one of three concentrate mixes. Concentrate mix 1 contained, in percent, ground yellow corn, 67.6; soybean oil meal, 16.2; salt, 0.5; bonemeal 1.4; sugar 4.8 and ACM (16%) 9.5. In concentrate mix 2 the ACM was replaced by 4.5% AFR and in mix 3 it was replaced by 3.8% cottonseed meal; corn sugar

TABLE 1. AVERAGE PERCENTAGE COMPOSITION OF RATIONS AND SELECTED FEEDS [a]

Rations and feeds [b]	Trial	Dry matter	Composition of dry matter, %				
			Ash	Protein (N×6.25)	Ether extract	Crude fiber	N-free extract
		%					
ACM (16%), ration	1	89.6	5.9	13.5	3.2	11.3	66.1
AFR, ration	1	90.4	6.2	14.2	3.0	13.0	63.6
C.S. meal, ration	1	90.1	5.9	13.5	3.2	11.4	66.0
ACM (16%), ration	2	90.0	4.9	13.9	2.8	12.1	66.3
C.S. meal, ration	2	90.2	5.2	14.2	3.1	12.3	65.2
ACM (16%), ration	8	87.7	6.2	9.5	1.8	26.5	56.0
ACM (33%), ration	8	90.0	5.8	10.5	2.0	29.5	52.2
Dead grass, pasture	5, 6	94.2	7.6	3.4	2.6	35.6	50.8
Blackstrap molasses	6, 7	71.7	9.6	5.4			85.0
ACM (16%)	1, 2	74.8	8.2	21.2			70.6
ACM (16%)	4, 5, 8	68.2	8.9	24.5			66.6
ACM (33%)	4	62.7	11.8	48.9			39.3
ACM (33%)	7, 8	64.9	6.9	51.0			42.1
AFR	1, 3	94.2	6.8	36.5	0.4	54.8	1.5

[a] All feeds were analyzed. Those not shown were of average composition.
[b] ACM=Ammoniated cane molasses, 16 and 33% protein equivalent. AFR=Ammoniated furfural residue.

and 9.5% molasses were added to both mixes to make 100%. The two ammoniated products and the cottonseed meal supplied about 10% of the total nitrogen of the rations in which they were used.

Collection periods were of 10 days duration preceded by 14-day preliminary periods. In the first two collection periods feces were caught in canvas bags (Garrigus and Rusk, 1939); in the third period, both feces and urine were collected from the animals in metabolism stalls (Nelson *et al.*, 1955). The procedures were the same in other details as described by Fontenot *et al.* (1955). There were no feed refusals.

Trial 2, metabolism. This trial was a comparison of ACM (16%) with cottonseed meal. Essentially it was a repetition of the third period of trial 1 except that only rations 1 and 3 were fed, each ration being fed to four comparable steers.

Trial 3, feed-lot. Twenty Hereford steer calves, after a 20-day standardization period, were divided according to weight and live grade into

two equal lots. The calves weighed 470 lb. when started on their respective rations and were group-fed for 163 days. The daily ration for each lot was corn (full-fed) plus 1.0 lb. alfalfa hay, 7.9 lb. sorghum silage and a protein supplement. The protein supplement was 1.5 lb. cottonseed meal for lot 1 and a combination of 0.75 lb. cottonseed meal and 0.90 lb. AFR for lot 2. The two supplements supplied equal amounts of nitrogen, half of the nitrogen in the latter supplement being derived from the AFR. The amount of corn in the rations was increased at the rate of 0.5 lb. per day every third day until the calves were on full feed of corn. A mineral mixture of salt and bone meal (2:1) was available to all lots. The calves were weighed every 21 days and on three consecutive afternoons at the beginning and end of the trial.

Trial 4, feed-lot. Three lots of 10 Hereford steer calves weighing about 515 lb. were used to compare protein supplements containing ACM (16%), ACM (33%) and cottonseed meal. This trial of 166 days was conducted in the same manner as trial 3 except that one-day initial weights and final weights of the calves were taken after 16-hour shrink periods. The daily ration for all lots was rolled milo (full-fed), plus 1.2 lb. alfalfa hay, 8.5 lb. corn silage, minerals (ad lib.) and protein supplement. The protein supplements which supplied equal amounts of nitrogen were 1.4 lb. cottonseed meal for lot 1, 0.7 lb. cottonseed meal and 1.7 lb. ACM (16%) for lot 2, and 0.7 lb. cottonseed meal plus 0.9 lb. ACM (33%) for lot 3. The ACM was poured over the grain and roughage at feeding time.

Results with Fattening-Type Rations

Results and Discussion

Trials 1 and 2. As shown in table 2, the average digestibility of total nutrients was only slightly less in the rations containing the ammoniated products than in the cottonseed meal rations. Differences between rations were not statistically significant at the 5% level of probability. By combining the results of trials 1 and 2, a difference in the digestibility of protein in favor of the cottonseed meal ration was significant at the 6% level of probability. Since the supplements under comparison supplied only 10% of the total nitrogen in each ration, differences between them in nitrogen digestibility would have to be large in order to affect the digestibility of total nitrogen. However, Tillman and Swift (1953) in feeding soybean meal ration to sheep obtained a marked decrease in the digestibility of nitrogen when ACM supplied 20% of

TABLE 2. DIGESTIBILITY OF TOTAL RATION NUTRIENTS, AND AMOUNTS OF NITROGEN RETAINED BY STEERS [a]

Trial	Ration designation	Percentage digestibility, % [b]						Nitrogen			
		Dry matter	Organic matter	Protein (N×6.25)	Crude fiber	Ether extract	N-free extract	Intake	Feces	Urine	Retained
								gm.	gm.	gm.	%
1	ACM	77.5	77.2	64.1	73.3	82.9	83.8	63.4	23.9	31.9	12
		1.8	2.6	2.7	2.0	3.4	1.7				4.9
1	AFR	76.7	79.1	63.7	71.7	84.7	83.6	64.8	24.0	29.5	17
		1.6	1.5	4.1	4.0	1.5	1.7				5.5
1	C.S. meal	78.5	80.1	66.0	72.0	88.1	85.2	62.5	21.5	31.9	15.0
		1.3	1.1	2.5	5.0	1.2	2.6				1.4
2	ACM	76.1	77.9	63.8	63.8	66.9	83.9	63.4	23.0	19.2	33
		1.3	1.1	1.2	3.1	3.4	2.4				6.9
2	C.S. meal	76.8	78.5	66.0	67.4	72.6	83.7	65.0	22.1	23.7	30
		1.9	2.0	2.1	3.2	4.7	1.8				6.1

[a] Trial 1, digestibility values were obtained for all nutrients in periods 1 and 2 and only nitrogen values obtained in period 3. Trial 2, digestibility and nitrogen value were obtained with four steers on each ration.
[b] Numbers below values are standard deviations.

TABLE 4. AVERAGE WEIGHT GAINS OF HEIFERS AND COWS ON WINTERING-TYPE RATIONS, POUNDS

Items compared	Range, 116 days Trial 5, lot no.			Range, 116 days Trial 6, lot no.			Dry lot, 50 days Trial 7, lot no.		
	1 CSM	2 ACM	3 ACM sprayed	1 Mol.	2 ACM	3 ACM sprayed	1 Mol.	2 ACM	3 Urea
Initial weight	725	720	720	749	745	742	650	649	652
Final weight	742	799	758	754	753	734	624	636	645
Total gain	17	79	38	5	8	—8	—26	—13	—7
Daily gain	0.15	0.68	0.33	0.04	0.07	—0.07	—0.52	—0.26	—0.14

the total ration nitrogen. Davis *et al.* (1955) have reported similar results with dairy cattle. Results of the present study point in the same direction. Nitrogen retention values which ranged from 11% to 17% of the intake did not differ significantly between rations.

Trial 3. The results in table 3 indicate a small advantage of cottonseed

TABLE 3. AVERAGE DAILY GAIN, FEED EFFICIENCY AND CARCASS GRADES OF STEERS ON FATTENING RATIONS

	Trial 3. 163 days		Trial 4. 166 days		
Item	Lot 1 CSM	Lot 2 CSM+ AFR	Lot 1 CSM	Lot 2 CSM+ ACM 16%	Lot 3 CSM+ ACM 33%
Initial weight, lb.	472	472	514	513	515
Final weight, lb.	838	801	837	862	866
Daily gain, lb.	2.24	2.02	1.95	2.10	2.11
Feed per 100 lb. gain, lb.					
Corn	485	546			
Milo			659	652	625
Cottonseed meal	67	37	69	36	36
Alfalfa hay	45	50	59	54	53
AFR		45			
ACM (16%)				81	
ACM (33%)					40
Silage	353	392	436	419	409
U. S. carass grade					
Prime	0	1	0	3	0
Choice	10	6	9	7	10
Good	0	3	1	0	0

meal over AFR; the steers on the cottonseed meal supplement gaining an average of 0.22 lb. more per day, and all of them grading choice. Further, they required less feed per 100 lb. gain. The steers fed AFR failed to make uniform gains. Although two of them made the greatest individual gains, all the steers of that lot gained slowly during the first 42 days. Slow initial gains of steers fed ammoniated products have been reported by Tillman and Kidwell (1951). That such initial response of steers to AFR is related to change in rumen microflora is indicated in the *in vitro* studies of Davis *et al.* (1955).

Trial 4. The results in table 3 show small differences in gain, feed requirement and carcass grade in favor of the ration containing ACM (33%). Gain differences were not statistically significant. Steers fed the ammoniated products ate more grain and silage. Small amounts of

molasses usually stimulate feed consumption, consequently differences in molasses content of the three rations may have contributed to the results. All steers fed the ACM ration graded choice or better.

Experiment with Wintering-Type Rations

Procedure

Trial 5, winter range. Thirty open two-year-old heifers were divided on the basis of weight into three lots of 10 animals each. All lots were allowed to run in individual pastures of weathered native range grass, the lots being rotated among the pastures every 28 days. Lot 1 was fed a supplement of 2.0 lb. cottonseed meal. Lot 2 was fed 1.3 lb. cottonseed meal and 1.8 lb. of ACM (16%). Lot 3 was fed 1.3 lb. of cottonseed meal and given access to 1.8 lb. of ACM diluted with water and sprayed on a small area of the dead winter grass. The supplements supplying equal amounts of nitrogen, were provided every other day in double amounts during a 116-day test. A mineral mixture of salt and steamed bone meal (2:1) was fed *ad libitum*. Initial and final weights were taken after a 16-hour shrink period during which time the animals were away from feed and water. Interim weights were taken at 28-day intervals.

Trial 6, winter range. Eighteen yearling heifers and 24 three-year-old cows were divided into lots of three, each lot having six heifers and eight cows. All lots were allowed to graze individual pastures of weathered native range grass and were rotated among the three pastures every 28 days. All animals received 1.0 lb. of cottonseed meal daily. The animals in lot 1 received in addition a daily supplement of 1.5 lb. of blackstrap molasses; those in lot 2 received 1.5 lb. of a mixture containing 75% blackstrap molasses and 25% ACM (33%); and those in lot 3 received the same mixture as lot 2, the mixture being sprayed on the grass as in trial 5. Thus lots 2 and 3 received extra nitrogen as ACM. Other details were as described in trial 5.

Trial 7, wintering in dry lot. Eighteen yearling heifers were divided on the basis of weight into three lots of six per lot. They were group fed in dry lots a daily ration of 12 lb. of wheat straw, 1.1 lb. of ground milo, and 2 gm of stabilized vitamin A. In addition, lot 1 received daily 2.5 lb. of blackstrap molasses; lot 2 received 2.5 lb. of ACM (33%), while lot 3 received 2.2 lb. of blackstrap molasses containing 0.3 lb. of urea. Thus, lots 2 and 3 received added and equal amounts of nitrogen supplied as ACM and urea, respectively. These molasses feeds were

poured over the milo at the time of the daily feedings. Bone meal and salt (1:2) were available. The animals were fed for 50 days and weighed as in trial 5.

Trial 8, digestion. This trial was conducted to determine by "difference" procedures, (Morrison, 1951) the digestibility of the ammoniated cane molasses feeds. It was of a 3 × 3 latin square design involving three digestion periods with the following three rations (1) prairie hay, 3629 gm. and minerals (bone meal and salt, 2:1) 90 gm., (2) prairie hay, 3629; minerals, 60 and ACM (16%), 1361 gm., (3) prairie hay, 3629; minerals, 60 and ACM (33%), 681 gm. The subjects which were nine grade Hereford yearling steers weighing 550 lb. were randomly allotted to the three rations. They were stanchioned twice daily while being fed; at other times they had the freedom of large stalls equipped with automatic waterers. Feces were collected in canvas bags during 10-day periods preceded by 14-day preliminary periods. There were feed refusals and the character of the ration made it difficult to obtain representative samples of the refused feed for chemical analysis.

Trial 9, "stimulation" test. This trial was an attempt to produce the condition described by others (Barrentine and Darnell, 1954; Richardson *et al.*, 1954) as "stimulation" in animals fed certain ammoniated products. During two years of work with ammoniated molasses at this Station only a few mild cases of stimulation had been observed and none of these had resulted in physical injuries.

Six yearling steers of dairy breeding were fed in dry lot 9 lb. of ration composed of cottonseed hulls, 6; ground milo, 2; cottonseed meal, 1; and minerals, 0.13 lb. For three days they received in addition, 1 lb. of ammoniated "high-test" molasses daily. This product was Cuban cane molasses in which about 50% of the sucrose had been inverted prior to the addition of ammonia. Its nitrogen content was equivalent to 32.2% protein. After three days, the amount was increased to 2 lb. daily, and feeding continued until the animals showed signs of "stimulation."

Results and Discussion

Trials 5, 6, and 7. The results of the three feeding trials with wintering-type rations are shown in table 4. In trial 5, the substitution of ACM (16%) for a nitrogen equivalent amount of cottonseed meal improved gains of the cattle significantly ($P<0.01$) when the ACM was fed with the meal in the feed bunk (lot 2). When the ACM was sprayed on the pasture forage (lot 3), the improvement in gains was less.

Variation in grazing intensity related to the area sprayed, and loss of nutrients in spraying present a problem in offering feed in this manner. Practical aspects of this problem have been discussed in greater detail by Pope *et al.* (1954, 1955). Since 1.8 lb. of ACM were required to replace the nitrogen of 0.7 lb. of cottonseed meal, differences in energy intake among the three lots probably favored lot 2; and, this may explain the greater gain. Further, molasses supplies minerals which have been shown to stimulate the activity of rumen microorganisms *in vitro* (Burroughs *et al.*, 1951) and, under certain conditions, to increase the digestibility of low grade roughage such as cottonseed hulls (Tillman *et al.*, 1954). The value of ACM in the present trial may have been due, in part, to factors other than nitrogen. The results of trial 6 bear upon this point.

In trial 6, the gains of the cattle fed ACM (lots 2 and 3) were not significantly different from those fed blackstrap molasses (lot 1). Thus, the small weight changes appeared to be more closely related to energy intakes, assuming these to be about equal, than to difference in nitrogen content of the supplements. Although the ACM supplement supplied about three times as much nitrogen as the blackstrap molasses, it failed to promote greater gains.

In trial 7 selective grazing was eliminated as a possible factor affecting results, and ACM compared with urea-molasses as a supplement to poor quality roughage. All the animals on these rations of wheat straw and supplement lost weight. Although differences in weight changes between lots were not statistically significant, average results which favored the urea ration indicated, at best, inefficient nitrogen utilization under these conditions.

Trial 8. The results of this digestion trial are given in table 5. In trial 8 in which ACM (16%) and ACM (33%) were fed in nitrogen equivalent amounts at levels to supply 55% of the total ration nitrogen, digestibility of dry matter, calculated by difference, was 73.8 in the two products and digestibility of protein 59.7 and 58.4%, respectively.

Values of 52% and 53% for the digestibility of protein in the supplemented rations are not unlike those reported for rations of prairie hay and cottonseed meal of similar protein content. As compared to cottonseed meal, the digestibility of protein (59%) in the supplements is low.

Ammoniated products vary in amount of free and bound ammonia and in lability of the NH_4-complex. Such variation which affects the digestibility of the nitrogen needs to be brought under control before a final assessment can be made of the nutritive value of the product.

TABLE 5. DIGESTIBILITY OF NUTRIENTS IN WINTERING-TYPE RATIONS AND IN SUPPLEMENTS OF ACM

Comparisons	Trial no.	Supplement amount [a]	Ration protein		Digestibility coefficients, % [b]					
			Total	From supplement	Dry matter	Organic matter	Protein (N×6.25)	Crude fiber	Ether extract	N-free extract
		gm.	%	%						
Rations										
Prairie hay alone	8		5.4		63.1	64.4	44.1	69.9	38.8	63.8
					5.7	4.9	7.6	4.4	3.9	5.6
Prairie hay+ACM (16%)	8	1361	9.5	55	65.6	67.6	52.6	70.5	34.5	70.1
					4.3	3.4	4.6	4.6	10.5	3.0
Prairie hay+ACM (33%)	8	681	10.5	54	64.2	66.5	51.8	73.4	37.7	66.4
					6.5	6.2	8.8	5.2	10.1	6.0
Supplements										
ACM (16%)	8	1361			73.8	79.9	59.7			88.6
					16.9	14.7	6.0			10.1
ACM (33%)	8	681			73.8	82.4	58.4			87.6
					16.9	14.6	9.9			16.2

[a] Supplement fed daily with 3629 gm. of prairie hay.
[b] Numbers below values are standard deviations.

Hershberger *et al.* (1955) have reported a relationship between the free ammonia content of such products and the availability of their nitrogen for bacterial protein synthesis. Nitrogen balance experiments with sheep (Tillman *et al.*, 1956) support a similar conclusion.

Trial 9. None of the animals in this trial showed stimulation when only 1 lb. of the ammoniated high-test molasses product was fed daily for 3 days. On the second day of feeding at the two-pound level (5 days on feed) four of the six animals receiving the ACM were highly stimulated. One of these was physically injured because of the close quarters and had to be killed. Thereafter, to avoid further injury, the cattle were turned out to pasture as soon as possible after stimulation. Another animal on this level was injured while in the pasture. Another one which had been put back in the holding pen 30 hours after the last feeding of ACM, when fed, became stimulated a second time. He injured himself in an attempt to jump out of the pen and had to be killed. About the same time one of the original group became stimulated; thus, five of the six animals reacted within 4 days after receiving the two-pound level and only two of these five survived.

Apparently the stimulatory agent is concentrated to a greater extent in the ammoniated high-test molasses product than in the ammoniated cane molasses (16% and 33%). Because of their violent response, animals stimulated by these products not only injure themselves, but become a hazard to personnel.

Summary

Feed lot trials conducted with steers fed fattening rations containing ammoniated cane molasses (ACM) and ammoniated furfural residue (AFR) indicated that the nitrogen of these products was not well utilized. The results were confirmed in digestion and nitrogen balance trials with fattening-type rations. Wintering trials with cattle gave evidence both for and against efficient utilization of the nitrogen in ACM fed as a supplement to dead winter range grass or wheat straw. Spraying the product on the dead range grass as a means of increasing forage intake gave poor results.

The digestibility of ACM (16% and 33% protein equivalent) was determined in trials in which both products were fed as supplements to prairie hay. The digestibility of crude protein ($N \times 6.25$) in the ACM products, which supplied 55% of the total ration nitrogen, was only 59%.

Feeding cattle a high test ammoniated molasses (32.2% protein

equivalent) at a level of 2 lb. per day produced a peculiar stimulation within 5–6 days. For short periods cattle so stimulated reacted with violence and injured themselves by running into and attempting to climb fences in a manner of extreme excitement.

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THE INFLUENCE OF VARIOUS FACTORS ON SURFACE TENSION AND pH OF RUMEN FLUID [1, 2]

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ALTHOUGH rumen ingesta have been employed extensively as research material in many kinds of investigations, including bloat studies, information on the influence of various factors involved in the collection, processing and analysis of ingesta samples is sparse. However, relevant comments occasionally appear in reports of other research. The present investigation was designed to evaluate the effects of time and method of collection, of method of processing, and of certain additives (both *in vivo* and *in vitro*) on surface tension and pH of rumen fluid.

Experimental

In these experiments surface tension and pH were estimated with a Cenco-duNouy interfacial tensiometer and a model H2 Beckman pH meter, respectively. Each surface tension value represents the average of at least four consecutive tensiometer readings. Careful standardization of procedure resulted in consecutive readings which were quite consistent (range usually less than 1 dyne).

Effect of Method of Sample Collection

Rumen ingesta samples were collected orally and via rumen fistulas from three steers. The oral samples were collected with stomach pump and tube and were primarily liquid, whereas the fistula samples were taken from a region slightly ventral and medial to the fistula, from the semi-solid stratum of rumen ingesta.

Surface tension and pH values are shown in table 1. The data were analyzed statistically by analysis of variance (Snedecor, 1946). Collection route had a significant effect ($P<.01$) upon pH values, higher values being obtained for samples collected orally. This marked effect is logical inasmuch as saliva contamination risk is much greater when rumen samples are collected orally. The surface tension values for

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rumen fluid collected by the two routes were not appreciably different; however, differences might have been observed if additional areas within the rumen had been sampled.

Effects of Pre-analytical Preparation, Time Following Collection, Sample Temperature, and Storage

Rumen ingesta as withdrawn cannot be employed for determining surface tension; yet radical treatment, such as centrifugation, may be

TABLE 1. SURFACE TENSION AND pH OF RUMEN FLUID COLLECTED ORALLY AND VIA FISTULA

Animal[a]	Surface tension		pH	
	Oral	Fistula	Oral	Fistula
	(dynes/cm.)			
3893	52.5	53.7	7.45	5.75
3821	49.6	54.4	8.40	6.45
3821	55.2	51.1	6.55	6.15
3903	55.1	53.9	7.35	6.15
3903	48.9	50.6	6.95	5.95
3903	58.6	56.6	6.75	5.65
3903	57.9	55.1	6.35	6.35
3903	59.4	58.8	7.15	6.60
3903	58.4	55.9	7.20	6.75
3903	54.6	57.4	7.85	6.90
3903	54.7	57.0	7.30	6.80
3903	54.4	56.7	7.85	6.55
3903	57.1	49.4	7.15	5.55
Av.	55.1	54.7	7.25	6.28

[a] Samples from 3903 taken at intervals over a period of 3 months.

undesirable since the fluid may no longer be representative of that found in the rumen. Inasmuch as surface tension is one of the properties which is currently under investigation as a possible etiological factor involved in the bloat syndrome, an experiment was conducted to establish the degree of sample refinement and the temperature necessary for good precision with a minimum of sample alteration.

Rumen fluid, collected via stomach pump and tube, was strained through cheese cloth (4, 16 or 32 layers) to remove the larger particles. An aliquot of that strained through 32 layers was then centrifuged for 5 minutes at a speed of approximately 1600 r.p.m. in an International Centrifuge, size 2, with a 16-place head. Aliquots of each of the four degrees of refinement were adjusted to 17, 27, 33, 37 and 47° C. imme-

diately prior to surface tension determination. Six consecutive tensiometer readings were taken for each aliquot at each temperature. The data are summarized in table 2. Although the most consistent readings were obtained using samples strained with four layers of cheese cloth and read at 37° C., readings nearly as consistent were obtained using

TABLE 2. EFFECT OF TEMPERATURE AND REFINEMENT OF ALIQUOTS OF A RUMEN FLUID SAMPLE ON SURFACE TENSION (dynes/cm.)

Sample temp.		Layers of cheese cloth			
		4	16	32	Centrif.
(° C.)					
17	Av.	56.2	58.2	56.9	59.6
	Range[a]	2.4	1.7	1.3	2.1
27	Av.	53.4	54.3	58.1	56.9
	Range	0.7	0.9	1.0	1.6
33	Av.	53.3	57.4	57.4	54.5
	Range	0.8	1.3	0.7	1.8
37	Av.	52.6	55.1	58.1	53.3
	Range	0.6	0.8	0.7	1.7
47	Av.	52.2	52.6	53.5	52.7
	Range	1.4	2.2	1.6	2.1

[a] The range is the difference between the highest and the lowest values.

four layers and read at 27° C. (room temperature). For surface tension determinations it appeared desirable to adopt the four layer-room temperature standards inasmuch as (a) precision of tensiometer readings is high, (b) samples can most easily be maintained at room temperature and (c) sample alteration from the *in vivo* status is relatively small.

The effects (upon rumen fluid surface tension and pH) of a short delay between sample collection and surface tension and pH measurements were studied by collecting samples several times daily for several days from six dairy cattle receiving four different kinds of rations varying from high roughage-low concentrate to high concentrate-low roughage. Each sample was divided into two aliquots; one was gradually cooled to 15° C. and the other was maintained at approximately 37° C. Initial surface tension and pH determinations were made as rapidly as possible (within 1 to 2 minutes after collection of ingesta). Surface tension and pH of both the 37° C. and 15° C. aliquots were determined periodically, then the aliquots at 15° C. were warmed to 37° C. and values were re-determined. As indicated in figure 1, surface tension of the rumen fluid rapidly increased while cooling to 15° C.

(which required about 30 minutes). Little change occurred between 30 and 120 minutes post-collection. Surface tension returned to the initial level upon warming an aliquot to 37° C. In contrast, the surface tension of the aliquot maintained at initial temperature remained relatively constant. Apparently neither sample temperature nor time following collection appreciably affected pH although a slight decrease was noted for the sample maintained at 37° C.

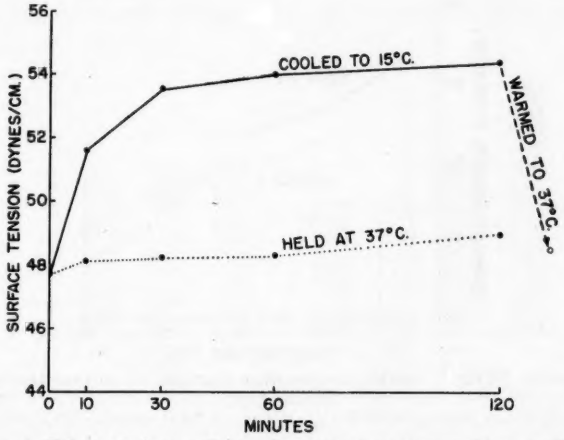

Figure 1. Effect of time and sample temperature on surface tension of rumen fluid.

Subsequently, one representative sample from each of four cattle (representing the four rations mentioned previously) was selected and aliquots were adjusted to temperatures ranging from 5 to 47° C. The surface tension of each sample was determined at each designated temperature (see figure 2). These data support those of figure 1 in that surface tension decreased with increase in sample temperature.

The effect of longer, deliberate delays between sample collection and determination of the surface tension and pH was investigated. Determinations were made at room temperature (27° C.) on samples of rumen fluid soon after withdrawal and after storage in screw-capped jars for 3, 6, 9, 12 and 15 hours at room temperature. Maximum mean changes from initial values were 2 dynes for surface tension and 0.3 for pH. Surface tension and pH evaluations were made on other samples at the end of each 24-hour period during storage at room tem-

perature for 1 week. Changes were only slightly greater than for the 15-hour period. Rumen fluid samples stored under refrigeration (8–10° C.) were employed to determine the long-time (up to 42 days) effect of storage. Surface tension and pH changes were small, although progressively becoming larger and more erratic, particularly beyond 21 days of storage. The more erratic changes occurring later in the storage period may have been due, at least partially, to mold growth.

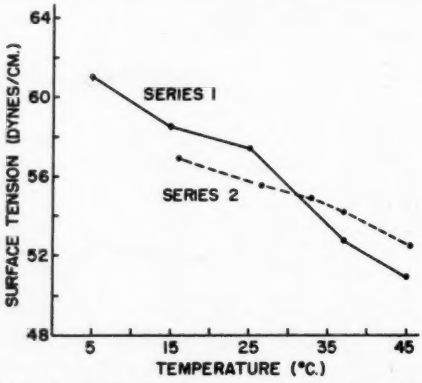

Figure 2. Effect of sample temperature changes on surface tension of rumen fluid.

Diurnal and Day-to-Day Variations

To ascertain the extent of diurnal variation, rumen fluid samples were collected from four cattle at uniform time intervals throughout a 15-hour period beginning at 6:00 a.m. Day-to-day variation was studied by collecting rumen fluid samples at 10:00 a.m. for 3 days from five dairy cattle which were under a constant feeding and management routine. Surface tension on each sample was determined in a manner designed to minimize variables other than hour or day of collection. Analysis of the data indicated a significant diurnal variation in both surface tension and pH.

Surface tension varied significantly also from day-to-day, such variation occurring in all of the cattle employed. The direction of day-to-day change was not uniform among nor constant within animals.

Effect of Dilution of Rumen Fluid With Water and Saliva

Under normal circumstances the rumen contents frequently are diluted by the ingestion of large quantities of water. Furthermore, the

quantity of saliva added to the ingesta *in vivo* is of considerable magnitude and, as indicated earlier, significant amounts of saliva may be incorporated in the collection of samples. Therefore, to assist in selection of the best time (for example, in relation to water ingestion) and technique for sample collection it seemed desirable to ascertain the effects of dilution with water and saliva on the surface tension of rumen fluid.

Rumen fluid samples were collected from two dairy animals, one having foamy ingesta and the other one non-foamy ingesta, and the

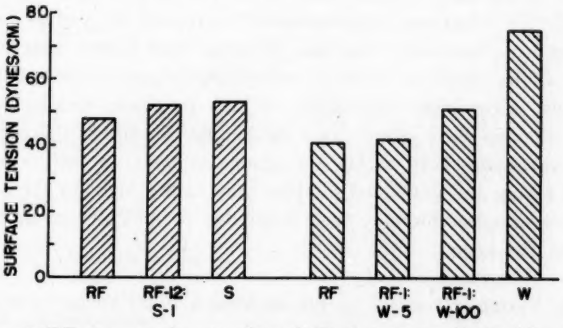

Figure 3. Effect on surface tension of diluting rumen fluid with water or with saliva (RF=rumen fluid, S=saliva, W=distilled water, ratios are V/V).

surface tension values were determined. Subsequently, aliquots of the samples were diluted with distilled water at various dilution rates ranging from 1 to 100 parts of water per part rumen fluid. Surface tension values of the altered rumen fluid samples were compared to the original values. In the case of the non-foamy ingesta, dilution with distilled water produced only a small change in surface tension (approximately 2 dynes) up to the ratio of 5 parts water per 1 part rumen fluid, and a change of only 10 dynes occurred in samples diluted with 100 parts of distilled water (figure 3). In the latter case the surface tension was still more nearly like that of an aliquot of undiluted rumen fluid than like that of distilled water. Similar but less marked changes occurred when foamy rumen fluid was used.

Rumen fluid samples obtained from two other dairy animals were similarly handled except dilution was with 1 part saliva (obtained from a lactating Holstein) per 12 parts rumen fluid. The addition of such

a small amount of saliva resulted in a surface tension reading more nearly like that of pure saliva than that of the pure rumen fluid. However, the surface tension of saliva was only slightly higher than that of rumen fluid.

Effect of Removal of Surface Foam From Rumen Samples

In foamy rumen fluid where a "top foam" existed rather than a "dispersed foam" manual removal was possible, and surface tension was determined on each such sample both before and after defoaming. Analysis of variance (Snedecor, 1946) of the data indicated a significant ($P<.01$) decrease (approximately 4 dynes) in surface tension following foam removal in the case of rumen fluid drawn from animals grazing alfalfa, whereas, in foamy rumen fluid drawn from animals on dry feeds, either high concentrate or high roughage, smaller surface tension changes were noted upon defoaming. However, the between-sample variations, both within and among animals, in surface tension of both foamy and defoamed samples were rather high. In the case of defoamed samples this may have been due to difficulty in uniformly removing the foam.

Effect of Various Chemical Agents on Rumen Fluid Surface Tension

The effect of various surface active agents [4] on the surface tension of rumen fluid was measured. Also direct determination of the surface tension of the liquid type agents (Tympanol, Rumene and turpentine) was possible. The results are summarized in table 3.

In vitro tests were made by adding the surface active agents to aliquots of rumen fluid as indicated in table 3. The surface tension values of rumen fluid aliquots were determined both before and after the *in vitro* addition of the various agents. Each *in vitro* surface tension value shown in phase 1, table 3 is an average of 12 tensiometer readings (three dairy cattle representing three different types of rations, four readings per animal).

In vivo tests were made by administering the agents to cattle and comparing surface tension values of rumen fluid drawn pre- and post-administration. For animals on the concentrate-dry roughage type rations samples were collected at ½, 3, 8 and 32 hours post-treatment,

[4] Tympanol (Jensen-Salsbery Lab., Kansas City) and Rumella (Allied Lab. Inc., Indianapolis) are methyl silicone type defoaming agents. Rumene (Allied Lab. Inc.) is a fatty acid type defoaming agent. Dreft (Procter and Gamble) is a household detergent. Ultrawet "K" (Atlantic Refining Co., Philadelphia) is an alkyl aryl sodium sulfonate type detergent.

and each "after treatment" surface tension value (table 3) is an average of 75 tensiometer readings (3 animals, 5 samples, 5 determinations per sample) on the samples taken at the post-treatment collection time when minimum surface tension occurred. The dosage levels for the various products are described in table 3. Ultrawet "K" was admin-

TABLE 3. EFFECT OF VARIOUS PRODUCTS ON RUMEN FLUID SURFACE TENSION (dynes/cm.)

	Tympanol	Rumene	Rumella	Turpentine	Dreft
Phase 1: Cattle on concentrate-dry roughage rations					
Product	31.8	25.7		29.4	
In vitro:					
Before addition of product	52.8	52.8	52.8	52.8	52.8
After addition of product[a]	36.4	36.8	45.7	44.4	33.8
In vivo:					
Before treatment	53.9	57.8	52.5	49.0	50.3
After treatment[b]	45.5	43.3	44.0	46.7	44.6
Phase 2: Cattle on alfalfa pasture					
				Ultrawet "K"	
In vitro:					
Before addition of product				49.8	
After addition of product (1:1000)				36.0	
In vivo:					
Control group (11 animals)				56.6	
Treated groups, 3 gm./100 lb. body wt. daily (11 animals)				48.6	

[a] Tympanol, Rumene and turpentine were added at the rate of 1 part per 1000 parts of rumen fluid; Rumella and Dreft at the rate of 0.63 and 0.24 grams, respectively, per liter.
[b] Dosage per 1000 lb. body wt.: Tympanol, 400 ml., Rumene, 400 ml.; Rumella, 125 grams; turpentine, 240 ml.; Dreft, 96 grams.

istered daily at the rate of 30 grams per 1000 pounds body weight for a total of 21 days, and samples were drawn at the end of the trial. For these animals receiving Ultrawet "K" each *in vivo* surface tension value shown is an average of 55 tensiometer readings (11 animals, 1 sample each, 5 determinations per sample). Surface tension of rumen fluid was reduced both *in vitro* and *in vivo* in all cases by the addition of the surface active agents at the dosage levels employed. Moreover, it was observed that surface tension reduction also occurred at lower dosage rates, the magnitude of the reduction being directly related to dosage rate. Likewise, surface tension reduction occurred both *in vitro*

and *in vivo* when trisodium phosphate and Ultrawet "60L" [5] were employed instead of the above agents.

Discussion

There has been some uncertainty regarding the effect of time between collection of rumen fluid samples and tensiometer readings upon surface tension values. The present data demonstrate that short delays between collection of rumen fluid and determination of surface tension do not affect the values appreciably if temperature of the sample is held constant. For convenience it may be desirable to make the surface tension measurements at room temperature. If this procedure is followed, care should be taken to insure measurement of all samples at the same temperature. The pH of rumen fluid apparently is not appreciably affected by temperature changes or by time.

The observed negligible effect on surface tension of dilution with water minimizes the importance of (a) using dry equipment in collecting, processing and analyzing rumen fluid for surface tension studies and (b) fluctuations in amount of water consumed by an experimental animal in relation to time of sample collection. Whether the dilution effect of relatively small quantities of water is also unimportant in relation to other rumen fluid properties was not determined.

Although relatively small amounts of saliva did alter the surface tension of rumen fluid, the great dilution factor *in vivo* and the similarity of saliva and rumen fluid surface tension values characteristic of most bovine diets may minimize the effect of the relatively small saliva contamination which occurs under careful experimental technique. Exceptions could occur if rumen fluid manifested surface tension values appreciably different from saliva and if gross contamination with saliva (which usually is avoidable) occurred during collection of the sample.

The effectiveness of various antifoaming agents has been investigated by Brunner (1950) and Dougherty and Meredith (1954). Although foamy ingesta frequently are characteristic of the bloat syndrome, the mechanism by which foam contributes to the pathology is not clear, nor is the interrelationship between foam and surface tension clear. However, the present research has shown that mechanical defoaming of samples of rumen fluid results in a lower surface tension. Such mechanical defoaming *in vitro* results in a violated sample, yet surface tension of a fluid cannot be measured accurately if a large amount of top-foam exists.

[5] Ultrawet "60L" (Atlantic Refining Co., Philadelphia) is 60% alkyl aryl sodium sulfonate type detergent and 40% water.

In the literature methyl silicones and turpentine have been repeatedly credited with increasing surface tension of rumen fluid. Most, if not all, such references ultimately refer to an article published by Clark (1948) wherein the statement was made that surface tension of rumen fluid is increased by the addition of commonly used antifermentatives, including turpentine. The experimental method by which such a determination was made by Clark is not clearly specified. Experimental data accumulated in the present research and reported in part in abstract form (Blake *et al.*, 1955) demonstrate that all agents employed (including turpentine and methyl silicones) decreased the surface tension of rumen fluid. Water and saliva were the only rumen fluid additives used in this experiment which increased surface tension. Therefore, one must assume that if the surface tension phenomenon is involved in the etiology of bloat and involved in any therapeutic value of the various surface tension-influencing bloat remedies, any relation between surface tension adjustment via these agents and subsequent reduction of bloat pathogenesis must involve a reduction rather than an increase of the surface tension existing in the rumen during bloat.

In an area of research as vast as rumen metabolic disorders it seems important to eliminate as many variables as possible, thereby providing a more common ground from which investigators can proceed. Perhaps the adoption, by investigators interested in ruminant research, of standard methods for preparing rumen fluid samples and evaluating the physical and chemical properties would be desirable in studying metabolic disorders involving the rumen. The confusion now present in the literature in regard to bloat etiology and treatment may be partially due to the lack of uniformity in techniques of collection and analysis of rumen ingesta.

Summary

The influence of various factors on surface tension and pH of rumen fluid of cattle was investigated. The pH of samples collected orally was higher than for samples collected via rumen fistula from the semi-solid stratum ventral and medial to the fistula. Surface tension values of rumen fluid collected by these two routes were similar.

Surface tension of rumen fluid was increased by cooling from 37° C. to 15° C. but remained essentially constant in samples maintained at 37°, 27° and 15° C., respectively, for periods ranging from 1½ to 15 hours. Dilution of rumen fluid with water effected relatively minor changes in surface tension; values for mixtures of 1 part of rumen

fluid to 100 parts of water were nearer those for rumen fluid alone than for water. Manual defoaming of rumen fluid samples reduced surface tension.

The products examined (turpentine, defoaming agents of the methyl silicone and fatty acid types, and two detergents) markedly reduced surface tension of rumen fluid.

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AN IMPROVED METHOD FOR THE DETERMINATION OF METABOLIC FECAL P [1]

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METABOLIC fecal phosphorus secretion is the major pathway of phosphorus loss from the body of the non-lactating ruminant. The determination of this loss is of importance to both applied and fundamental research. Nutritionists use metabolic fecal phosphorus to calculate the availability of phosphorus in foodstuffs; physiologists study changes in phosphorous absorption and secretion during adaptation to physiological and/or nutritional stresses. The determination of metabolic fecal phosphorus by the method of Kleiber *et al.* (1951) is complicated by the rapid disappearance of intravenously-injected P^{32} from the plasma. Lofgreen and Kleiber (1954) improved this method by injecting the isotope subcutaneously. We have developed still another technique which we believe significantly increases the value of these tracer trials. The new method utilizes radioactive phosphorus (P^{32}) which is injected as the insoluble salt, tricalcium-phosphate.

Four yearling lambs were used for these experiments. They were maintained in individual collection stalls and were fed alfalfa hay ad libitum. The isotope was injected as P^{32} labeled, calcium phosphate which was prepared as follows: 3.2 ml. of a calcium phosphate carrier solution containing 0.37 m moles H_3PO_4/per ml. and 1.27 m moles $CaCl_2$/per ml. were added to a 50 ml. centrifuge tube containing 6.25 ml. $H_3P^{32}O_4$ solution (3.2 mc. P^{32}/per ml.). Tricalcium phosphate precipitated when the pH was brought above 8.0 with 2n NaOH. The mixture was centrifuged and the supernatent was siphoned off. The precipitate was then resuspended in a stiff starch solution (5%) and brought to a final volume of 50 ml.

Each lamb received 11 ml. (4.4 mc) of this suspension. Two lambs were injected subcutaneously over the left shoulder; two lambs were injected intraperitoneally. Blood samples were taken at frequent intervals to 30 days after the injection.

[1] This study was partially supported by a grant from the United States Atomic Energy Commission.
[2] Department of Animal Husbandry, Davis.
[3] The authors wish to acknowledge the technical assistance of chemist Crawford F. Brown.

Feces were collected daily and were homogenized with water in a Waring Blendor. An aliquot was taken for ashing. Total phosphorus was determined after Sumner (1944); radioactivity was measured by the method described by Kleiber *et al.* (1951).

Metabolic fecal phosphorus was calculated after Lofgreen and Kleiber (1953a) this method involves the labeling of body phosphorus with radioactive phosphorus, P^{32}, and determining the proportion of fecal phosphorus originating from the labeled body phosphorus. The formula developed for calculating the proportion of metabolic phosphorus in the feces is

$$M=\frac{\phi\ (t+1)}{\pi\ (t)}$$

where π_t is the specific activity of the plasma inorganic phosphorus, (plasma trichloracetic acid filtrate) at time t and ϕ (t+1) is the specific activity of the fecal phosphorus one day later.

Results and Discussion

The curves on figure 1 show the plasma and fecal P^{32} specific activity for our lambs (1–4) and for those previously reported by Lofgreen and Kleiber (1954) (6 and 7). The close similarity of the curves for the two lambs on each experiment is a measure of the repeatability of each method. Lofgreen and Kleiber (1954) noted that the decrease in specific activity of plasma and fecal phosphorus was exponential from 0–7 days after the subcutaenous injection of P^{32} labeled, sodium phosphate. After 7 days, the specific activity was a linear function of time.

The uptake of P^{32} from calcium phosphate was more marked following intraperitoneal injection than after subcutaneous injection. In both cases, however, the plasma and fecal phosphorus specific activity curves appear to be linear from 3 to 4 days after the injection.

This early linearity offers the distinct advantage of increasing the total collection period to at least 12 days. Thus consecutive collections of 4 to 5 days duration can be made with each lamb. Consecutive determinations of metabolic fecal phosphorus increase the reliability of each experiment over that of a single determination. They also provide the opportunity to demonstrate changes in the relative absorption rate and relative metabolic fecal phosphorus secretion rate when different levels of calcium and/or phosphorus are fed.

Regression equations for the linear portion of each experiment were calculated by the method of least squares. The regression coeffiicents

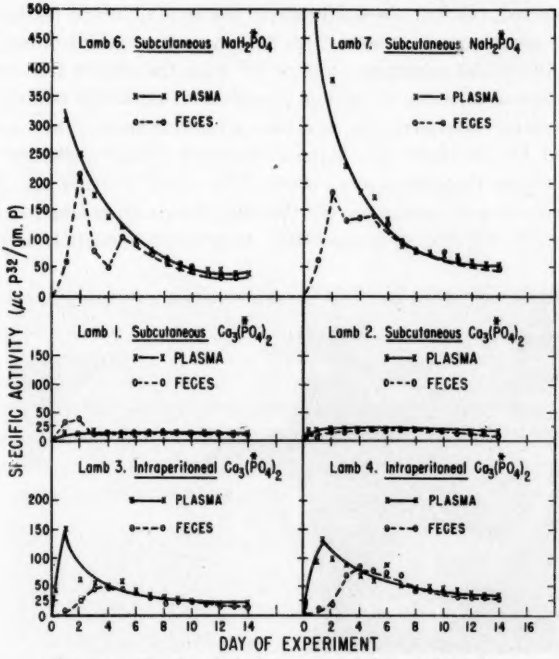

Figure 1. P^{32} levels in plasma and feces of lambs.

are listed in table 1. We note here that the use of P^{32} labeled calcium phosphate gives still another advantage over sodium phosphate, namely, it results in a marked decrease in the rate of disappearance of isotope from the plasma. This is particularly true for the trials with subcutane-

TABLE 1. THE DISAPPEARANCE OF PLASMA P^{32} AFTER THE INJECTION OF LABELED SODIUM AND CALCIUM PHOSPHATE

Compound injected	Method of injection	[a] Regression coefficient
[b] $NaH_2P^{32}O_4$	Subcutaneous	—6.3
$Ca_3(P^{32}O_4)_2$	Intraperitoneal	—3.8 (lamb 3) —4.6 (lamb 4)
$Ca_3(P^{32}O_4)_2$	Subcutaneous	—0.33 (lamb 1) —0.66 (lamb 2)

[a] Calculated from the linear portion of the plasma P^{32} specific activity-time curve by the method of least squares.

[b] Taken from Lofgreen and Kleiber (1954).

ously-injected, calcium phosphate where the level of P^{32} in plasma (and feces) is nearly constant from 3 to 30 days after the injection.

The uptake and subsequent loss of P^{32} from the plasma following the intraperitoneal injection of calcium phosphate is similar to that observed when sodium phosphate is injected subcutaneously. This may be explained by the fact that material injected intraperitoneally would tend to diffuse throughout the viscera. This would increase the chances for hydrolysis and absorption. On the other hand, when labeled calcium phosphate is injected subcutaneously, it tends to remain localized. In

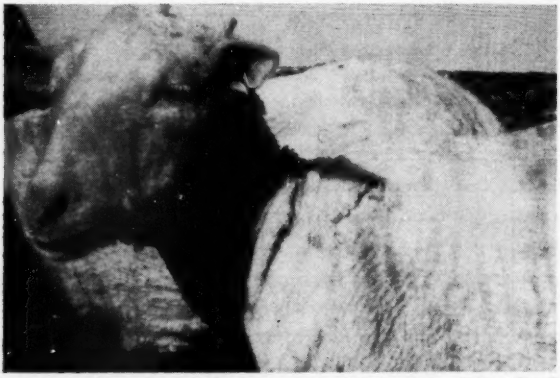

Figure 2. Callus formation at the site of injection of $Ca_3(P^{32}O_4)_2$.

fact, sufficient radioactivity remained at the site of injection to cause a radiation effect or "beta burn". This was first noticed as a marked reddening (erythema) about 30 days after the injection. Later, this area formed into a callus (figure 2) which slowly retracted and sloughed off about four months after the injection. There was no evidence that the injected P^{32} had any effect on the well being of the lambs. Daily food consumption remained normal and they were subsequently used in another series of digestion trials.

The daily rate of secretion of metabolic fecal phosphorus was calculated for each lamb. The results are listed in table 2. Metabolic fecal phosphorus secretion varied from 0.76 to 2.5 gm. per day and seems to be positively correlated to total fecal phosphorus. This relation is depicted in figure 3. Although food intake was not measured on these lambs, it seems probable that the increasing levels of metabolic fecal phosphorus reflect higher levels of food intake. This is supported by the

TABLE 2. CALCULATION OF THE DAILY METABOLIC FECAL PHOSPHORUS

Category of interest	Lamb No. 1	2	3	4
Specific activity of plasma TCF[a] on day 4	15	18	42	75
Specific activity of plasma TCF on day 13	12	13.5	18	33
Mean specific activity of plasma TCF for period (π)	13.5	15.6	30	54
Specific activity of fecal composite from fifth to fourteenth day (ϕ)	11.9	10.9	23.2	37.7
Ratio, (ϕ/π)	0.88	0.70	0.77	0.70
Total fecal phosphorus, gm./day	1.19	1.09	2.32	3.52
Metabolic fecal phosphorus, gm./day	1.1	0.76	1.8	2.5

[a] TCF = trichloracetic acid filtrate.

fact that in 3 of the 4 lambs the excretion rate of undigested fecal phosphorus also increased with increasing metabolic fecal phosphorus. Lofgreen and Kleiber (1953) and Lofgreen *et al.* (1954) determined the metabolic fecal phosphorus secretion rate in nine lambs to be nearly constant with constant food intake. In addition, Kleiber *et al.*

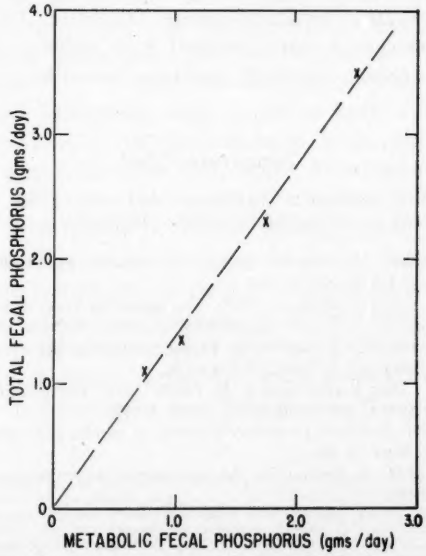

Figure 3. Correlation between the rate of metabolic fecal P secretion and total fecal P excretion.

(1951) with cows and Lofgreen *et al.* (1952) with calves showed that the secretion rate of metabolic fecal phosphorus was positively correlated to both total fecal phosphorus and to food intake.

In this respect it is interesting to note the similarity between the secretion rate of metabolic fecal phosphorus and metabolic fecal nitrogen. The secretion rate of metabolic fecal nitrogen has been shown to increase with the level of food intake (Mitchell, 1926), total fecal nitrogen and nitrogen intake (Lofgreen and Kleiber, 1953b), and dietary fiber (Meyer, 1956).

Summary

A method is described for the determination of metabolic fecal phosphorus. This method makes use of P^{32} labeled calcium phosphate which is injected either subcutaneously or intraperitoneally. Metabolic fecal phosphorus is calculated by comparing the level of P^{32} in the feces to that in the plasma 24 hours earlier. The daily rate of secretion of metabolic fecal phosphorus appears to be proportional to total fecal phosphorous excretion. Subcutaneous injection of labeled calcium phosphate gives a distinct advantage over both intraperitoneal calcium phosphate and intravenous sodium phosphate. The level of P^{32} in the plasma (and feces) reaches a nearly constant level within 3 days after the injection and remains essentially unchanged for at least 27 days thereafter.

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A COMPARISON OF BRAHMAN CROSSBRED WITH BRITISH CROSSBRED CATTLE [1]

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BRAHMAN cattle, which are noted for their hardiness and adaptability to the hot humid conditions prevalent in the lower South, have been crossed quite extensively in such areas in an effort to incorporate these characteristics into existing beef herds. Though this practice has been followed, experimental studies comparing the merits of Brahman-cross cattle with cattle of British breeding were not numerous when this study was initiated. This is especially true of comparisons involving British × British-cross with Brahman × British-cross cattle. An even smaller number of studies have been made wherein the production of the crossbreds as brood cows has been studied.

Rhoad and Black (1943) in reporting studies with native and grade Hereford cattle indicated that best results as measured by weights at birth, 6 months, and 2 years were obtained by first grading-up with Hereford bulls, then crossing the first generation offspring to Brahman bulls and finally backcrossing the hybrid offspring with Herefords. Baker and Black (1950) noted that Brahman × Angus-cross animals, when compared with Angus, were heavier at birth, 6 months, and 6 years of age, gained as fast and efficiently in the feedlot, yielded a higher percent of carcass, but had slightly lower carcass grades. The Brahman × Angus-cross cows produced calves that were heavier at 6 months than were calves from other crosses. Kidder and Chapman (1952) in reporting studies involving Brahman, Angus, and Devon cattle indicated that progeny of the first-cross in both reciprocal crosses of Brahman × Angus and Brahman × Devon matings were superior in birth weight and weight gains to either of the purebred lines of that cross. Lush *et al.* (1930) found that weaned weights of calves from Brahman × Hereford cows were heavier than those from Hereford cows.

[1] This work is a part of the Southern Regional Beef Cattle Breeding Project, S–10.

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In steer feeding studies Black *et al.* (1934) compared performance of Brahman × Hereford and Brahman × Shorthorn crosses with Herefords and Shorthorns. These workers indicated that Brahman crosses were heavier at weaning and at the end of 120 days of feeding than British-bred steers. When the feeding period ranged from 150 to 179 days, there was a tendency for this condition to be reversed. The British-bred steers gained somewhat faster and more efficiently and graded slightly higher than Brahman × British crosses; however, dressing percent was 2 to 4% higher for crossbreds. Ittner *et al.* (1954) reported studies involving Herefords, Shorthorns × Herefords, and Brahman × Herefords. In winter feedlot test comparisons, Herefords ranked first, Shorthorn × Herefords, second, and Brahman × Herefords, third in rate and efficiency of gain and feed consumption. Performance during summer in feedlot was very similar for those groups. Summer pasture studies indicated that Brahman × Herefords gained somewhat faster than Herefords. Carcass data indicated that Brahman × Herefords had lower carcass grades but higher dressing percentages than the other groups. Hubert *et al.* (1955) in studying growth and fattening reported that Brahman × Hereford crossbreds had no advantage over Herefords for Oregon.

The objectives of this present study were (1) to compare performance of British crossbred calves with Brahman × British crossbreds, and (2) to compare the performance of both crossbred groups as brood cows. Crossing both groups was considered important so that any benefits which might be obtained from the Brahman crossbred would be peculiar to the Brahman breed rather than to crossbreeding *per se*.

Experimental Procedure

Thirty-six grade Hereford heifers were used to raise the crossbred calves. Three calf crops were raised with the cows calving first as 3-year olds in the spring of 1950. Two Angus and three Brahman sires were used with one bull of each breed being used during a given year. Approximately equal numbers of cows were assigned to the different bulls each year. Although the offspring of these matings do not conform to the definition of crossbreds as being the progeny of purebred matings, they are hereafter referred to as crossbreds.

Previous winter treatment and breed composition were the principal factors considered in assigning the cows to bulls initially. The cows were again divided for breeding in the spring of 1950 and 1951 with winter feeding, breeding of cows and breeding of calves being the primary basis

for division. For the first and second calf crops approximately equal numbers of calves from each cross were raised in the same pasture. The third calf crop was raised together in one pasture. None of the cows were exposed to bulls of the same breed for the three calf crops. By following this breeding and management schedule, differences due to summer pasture, winter feeding, and individuality of cows which might have favored one or the other of the crosses were greatly minimized.

All cows were pastured from late March until late November and wintered either in dry lot or on a combination of dry lot and winter pasture feeding. The feeding program was comparable for breeding groups and was considered adequate for good animal performance. The cows were pasture-bred from approximately April 15 to July 10, resulting in the calves being born from late January through early April the following year. All calves were creep-fed a concentrate mixture of 6 lb. cracked corn and 1 lb. cottonseed meal from May until weaned around the middle of September.

All males were castrated within two months following birth. Since the calves were weaned at average ages of approximately 7 months, weights at weaning were standardized to 210 days of age by prorating gains from 28-day weights bracketing 210 days of age. This 210-day weight is hereafter referred to as weaned weight. Adjustments in birth and weaned weight data due to sex differences are discussed under the appropriate subjects. It was not necessary to adjust birth and weaning weight data for differences due to age of dam since similar age cows were used in each breed group.

The crossbred steer calves were slaughtered at weaning. Slaughter steer and carcass grade, and dressing percent were recorded. Slaughter steer and carcass grades for all calves in this study were recorded by a committee. Dressing percentages were calculated from actual weaned weight and chilled carcass weight.

Female offspring from the two crosses were retained to compare their performance in feedlot and later as brood cows. Immediately after weaning and following a 10- to 14-day preliminary feeding period, the heifers were full-fed in breed groups for 140 days a concentrate mixture (6 lb. cracked corn and 1 lb. cottonseed meal). Coastal Bermuda grass hay was fed ad lib. Following the feedlot test, the heifers were added to a single breeding unit over a period of 3 years. Eighteen of the 24 available Angus × Hereford heifers were saved. All heifers (6) were saved the first year. Of the nine heifers available for each of the other two years, six were randomly selected. Six Brahman × Hereford

TABLE 1. MEANS AND ANALYSIS OF VARIANCE OF PERFORMANCE FACTORS IN COMPARING ANGUS×HEREFORD WITH BRAHMAN×HEREFORD CALVES

Performance factor	Birth weight				Weaned weight				Slaughter grade [a]				Dressing percent				Carcass grade [a]				Feedlot gain			
	A×H		B×H		A×H		B×H		A×H		B×H		A×H		B×H		A×H		B×H		A×H		B×H	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
Means																								
1950	18	63.5	17	73.0	16	453	15	469	10	15.2	9	16.7	10	58.3	9	60.1	10	13.4	9	14.7	6	255	6	232
1951	16	66.4	14	69.9	15	460	12	497	6	12.0	6	11.0	6	51.8	6	53.6	6	12.3	6	13.3	9	239	6	222
1952	17	67.4	16	79.5	15	475	14	507	6	10.7	7	13.1	6	56.9	7	57.8	6	14.7	7	16.9	9	277	7	249
Total or weighted av.	51	65.7	47	74.3	46	463	41	490	22	13.1	22	14.0	22	56.1	22	57.6	22	13.4	22	15.0	24	257	19	235
Analysis of variance																								
Source	d.f.	m.s.			d.f.	m.s.			d.f.	m.s.			d.f.	m.s.			d.f.	m.s.			d.f.	m.s.		
Total	97				86				43				43				43				42			
Years	2	292.06			2	6554.20			2	93.06**			2	153.73**			2	28.50*			2	4248.89*		
Breeds in years	3	697.47**			3	6020.06			3	14.33			3	9.27			3	8.57			3	1884.42		
Error	92	104.84			81	2669.62			38	5.31			38	5.28			38	7.10			37	1014.15		

[a] Slaughter and carcass grades coded—10, 12, 14, 16, and 18=choice, low choice, top good, good, and low good, respectively.
* $P<.05$; ** $P<.01$.

heifers were saved each year which was a total of 18 of the 19 heifers weaned. The heifers were first mated to calve as 2-year-olds. Thus, approximately six animals of each cross were exposed for breeding in 1951, 12 in 1952, and 18 in 1953 and 1954. The first two calf crops were sired by Hereford bulls and the other two by Shorthorn bulls. All the females were mated to the same bull within a season. The first two calf crops were slaughtered at weaning. The heifers from the third calf crop were fed in dry lot 140 days then slaughtered while the steers were used in other studies. The fourth or 1955 calf crop was transferred to another state institution immediately after the calves were born.

An analysis of variance as described by Snedecor (1950) was calculated for all data. These analyses along with means for the various items are presented in tables 1 and 2.

Discussion of Results

Comparison of Two Types of Crossbred Calves

A 93% calf crop was born to cows exposed to Angus bulls while an 89% calf crop was born to cows exposed to Brahman bulls. Of the Angus-cross calves born, 92% were weaned while 87% of Brahman-cross calves born were weaned. Eleven of the 98 calves born were either stillbirths or died prior to weaning.

The question has frequently arisen as to whether calves of Brahman breeding are carried longer in utero than those of British breeding. Since cows in this test were pasture-bred, breeding dates were not known. The average interval from date bulls were placed in the pasture until the calves were born was 300 days for Angus-cross calves and 308 days for Brahman-cross calves. Approximately the same variation between breeds was noted in each of the three years. Whether the observed differences are due to longer gestations of the Brahman-cross calves, to timidity and delayed breeding activity of Brahman bulls, or merely to chance is not known.

Average birth weights of Angus $\times$ Hereford calves were 66 and 65.5 lb. for the 23 males and 28 females, respectively. Average birth weights of the 25 male Brahman $\times$ Hereford calves was 77.2 lb. or approximately 6 lb. heavier than those of the 22 female calves (71 lb.). In analyzing this data, adjustments for sex were not made since the weights of Angus-cross males and females were essentially the same and since sex ratios for both groups were rather normal. The mean

TABLE 2. MEANS AND ANALYSIS OF VARIANCE OF PERFORMANCE FACTORS IN COMPARING OFFSPRING OF ANGUS×HEREFORD AND BRAHMAN×HEREFORD COWS

Performance factor	Birth weight				Weaned weight				Slaughter grade[a]				Carcass grade[a]				Dressing percent			
	A×H		B×H		A×H		B×H		A×H		B×H		A×H		B×H		A×H		B×H	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
Means																				
1952	5	60.4	5	64.2	5	365	5	460	5	16.4	5	13.2	5	14.8	5	12.4	5	53.8	5	55.7
1953	11	60.9	9	64.9	10	408	9	458	10	12.0	9	11.3	10	15.8	9	15.1	10	57.4	9	56.7
1954	14	61.8	16	66.2	13	369	15	445	13	14.5	15	14.0								
1955	15	70.1	14	70.3																
Total or weighted av.	45	64.2	44	67.0	28	382	29	451	28	13.9	29	13.0	15	15.5	14	14.1	15	56.2	14	56.3
Analysis of variance																				
Source	d.f.		m.s.		d.f.		m.s.		d.f.		m.s.		d.f.		m.s.		d.f.		m.s.	
Total	88				56				56				28				28			
Years	3		315.96**		2		2766.46		2		46.90**		1		23.00		1		35.50**	
Breeds in years	4		65.13		3		24742.35**		3		9.73		2		8.33		2		5.27	
Error	81		62.58		51		2141.57		51		7.16		25		7.54		25		3.80	

[a] Slaughter and carcass grades coded—10, 12, 14, 16, and 18=choice, low choice, top good, good, and low good, respectively.
** $P<.01$.

birth weight of all Angus-cross calves was 65.7 lb. whereas the mean weight for all Brahman-cross calves was 74.3 lb. Differences in birth weights were highly significantly statistically.

Records of 87 weaned weights, 46 Angus-cross, and 41 Brahman-cross were available for study. Steer calves were approximately 30 lb. heavier than heifers for each cross. Since sex differences and sex ratios within crosses were approximately the same, adjustments for sex were not made. The average weaned weight for Angus-cross calves was 463 lb. The average weaned weight for Brahman-cross calves was 490 lb. which was 27 lb. heavier than the average for Angus-cross calves. The differences in weaned weight, however, were not statistically significant. Slaughter and carcass grades were obtained on 22 weanling steer calves of each cross. The respective means were 13.1 and 13.4 for Angus × Hereford calves as compared to means of 14.0 and 15.4 for the Brahman × Hereford calves. The mean dressing percent was 56.1 for the Angus × Herefords and 57.6 for the Brahman × Herefords. Although differences in grades and dressing percentages were not statistically significant, the differences observed tend to be in the same direction as those observed by other investigators and may well be real.

The mean 140-day post-weaning feedlot gain for the 24 Angus × Hereford heifers was 257 lb. The mean gain for the 19 Brahman × Hereford heifers was 235 lb. or 22 lb. less. This difference in gain was not statistically significant but again is in the same direction as observed by several other investigators. The Angus × Hereford heifers consumed slightly more total feed daily, more concentrate mixture but less hay, than the Brahman × Hereford heifers. The Angus × Hereford heifers also made slightly more efficient gains. These animals consumed a total of 858 lb. of feed per 100 lb. of gain whereas the Brahman × Hereford heifers consumed 872 lb. The findings presented above are generally in agreement with those of other workers as mentioned in the literature review.

Performance of Angus × Hereford and Brahman × Hereford Crossbreeds as Brood Cows

An 87% calf crop was born to Angus × Hereford cows while an 88% calf crop was born to Brahman × Hereford cows. Ninety-one percent of the calves born to Angus × Hereford cows were weaned (3 stillborn) while 97% of calves born to Brahman × Hereford cows were weaned (1 stillborn). These figures include survival to weaning for the 1955 calves. The average interval between the time the bulls were

placed in the pasture and when the calves were born was also calculated for both crossbred groups. This interval for the Angus × Hereford cows was 312 days and for the Brahman × Herefords it was 311 days.

Forty-five calves (16 males and 29 females) averaging 64.2 lb. at birth were born to Angus × Hereford cows, while 44 calves (11 males and 33 females) averaging 67 lb. were born to Brahman × Hereford cows. The average birth weights of calves of the two sexes were essentially the same for calves of the Angus × Hereford cows. Males were 5.2 lb. heavier than females for the calves born to Brahman × Hereford cows. It is interesting to note the lack of sex differences in birth weights of calves with Angus breeding in both phases of this study. Using the data without adjustment for sex, differences in birth weights of calves from the two crossbred cow groups were not significant.

Twenty-eight calves, 10 steers and 18 heifers, from Angus × Hereford cows were weaned at an average weight of 382 lb. The average weight of steers was 18 lb. heavier than that of heifers. Twenty-nine calves, 6 steers and 23 heifers, from Brahman × Hereford cows were weaned at an average weight of 451 lb. The steers weighed 57 lb. more than the heifers. No adjustment for weight due to differences in sex was made. Differences in weaned weight were highly significant statistically. The 18% increase in weaned weight of calves from the Brahman × Hereford cows over those from Angus × Hereford cows was probably the major advantage observed in this study of using part Brahman breeding. The extra weight resulted in fatter calves with considerably more bloom. For calves slaughtered at weaning this fact would be economically important.

Slaughter grades were recorded on all calves weaned. The mean slaughter grade for calves from Angus × Hereford cows was 13.9 as compared to a mean of 13.0 for calves from Brahman × Hereford cows. The mean carcass grade for 15 calves from Angus × Hereford cows was 15.5 whereas the mean grade for 14 calves from Brahman × Herefords was 14.1. Neither slaughter nor carcass grade differences were statistically significant. Dressing percent for the two groups was essentially the same.

The heifers from the 1954 calf crop, 9 from Angus × Hereford and 11 from Brahman × Hereford cows, were fed 140 days in dry lot as previously described. The average daily rate of gain was 1.96 lb. for both groups. The latter group of heifers consumed 0.5 lb. more feed daily and required 863 lb. of feed per 100 lb. of gain where the former group only needed 831 lb. feed per 100 lb. gain.

An analysis of the weights of cows at an average age of 3.5 years was made as an indication of mature weights. The 1954 fall weights were used. At this time approximately one-third of the cows were 4.5, one-third 3.5, and one-third 2.5 years of age. The mean weight for Angus × Hereford cows was 1000 lb. as compared to 987 lb. for Brahman × Hereford cows. This difference was not statistically significant.

These results also agree reasonably well with those of other workers. The study supports other studies in pointing out the advantage of the half-Brahman cow in reference to weaned weights (Rhoad and Black, 1943; Baker and Black, 1950; Lush *et al.*, 1930; and Kidder and Chapman, 1952). The 18% heavier calf produced by the Brahman × Hereford cow appears to be the major advantage in using the Brahman breed for crossing. Differences in birth weights from the two groups of cows were not significant. The slightly better slaughter calf grade for offspring from Brahman × Hereford cows was due principally to degree of finish. Sample numbers for carcass grade and dressing percent were rather limited and were not too valuable as an indication of these characteristics. A lack of differences in cow weights is not in agreement with other reports. Baker and Black (1950) reported that Brahman × Angus crosses were heavier at 6 years of age than Angus.

Summary

Records of 98 birth weights, 87 weaned weights, 44 slaughter grades, carcass grades and dressing percentages, and 43 feedlot gains were available for comparison in studying the performance of Brahman × Hereford and Angus × Hereford calves. The only statistically significant advantage of the Brahman × Herefords over the Angus × Herefords was heavier birth weights; however, these crosses were somewhat heavier at weaning and had a slightly higher dressing percent. The Angus × Hereford steer calves graded slightly higher as slaughter animals and as carcass beef, and also gained somewhat faster and more efficiently in feedlot than the Brahman × Herefords. None of these differences were statistically significant.

Cows of each cross were bred to either Hereford or Shorthorn bulls (both groups were bred to the same bull within a season) to compare the performance of the two crossbred groups as brood cows. The differences in birth weights noted in studying 89 records were not significant. Calves from Brahman × Hereford cows were 18% heavier (highly significant statistically) at weaning than calves from Angus × Hereford

cows. The average slaughter calf grade for the 57 calves weaned was slightly higher (not statistically significant) for calves from Brahman × Hereford cows. Limited data for carcass grades and dressing percent (29 records) and feedlot gain (20 records) indicated that there was little difference in the offspring of the two groups of cows in respect to these traits. Differences in cow weights taken at an average age of 3.5 years, as an indication of mature weights, were minor.

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A GENETIC STUDY IN STEER PROGENY GROUPS DURING SUCCESSIVE GROWTH PERIODS [1]

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THE utilization of roughages and concentrates by beef-cattle is of great importance to the economy of this nation. Furthermore, the ability of cattle to use these feeds efficiently during various growth periods is important in obtaining maximum production from our feed resources.

A number of studies in recent years have been made to determine the heritability of growth rate in beef cattle. Studies were made by Knapp and Nordskog (1946); Knapp and Clark (1947); Patterson *et al.* (1949); Knapp and Clark (1950); Kincaid *et al.* (1952); Shelby *et al.* (1955); and Patterson *et al.* (1955).

Heritability estimates of gain in the feedlot under full feeding conditions have varied from 0 to 99%. Most of the estimates approached a magnitude of 60%. As a consequence, a breeding animal which performs well in the feedlot can be expected to pass this desirable characteristic to its offspring which are to be fed on a similar nutritional plane. However, a large proportion of our beef animals are produced on the range. For this reason, the average rancher wants to know how the offspring of animals selected under winter feedlot conditions will perform under range conditions.

Some authors maintain that the most rapid progress will result when breeding stock is selected under an environment which will allow complete expression of the character. Others have taken the view that maximum genetic progress may not be obtained if the commercial offspring are to be reared under a less favorable situation. They believe that selection should be made under an environment which is as nearly identical with the commercial application as possible.

Falconer and Latyszewski (1952) studied the effects of environment

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in relation to selection for size in mice. Improvement of the genotype for growth on a high plane did not result in appreciable improvement for growth on a low plane. In contrast, improvement of the genotype for growth on a low plane resulted in improvement for growth on a high plane.

This paper presents the results of an experiment conducted at the North Montana Branch Station designed primarily to compare genetic relationships between growth potentials during three periods involving different levels of nutrition.

Procedure

The Hereford steer calves used in these feeding trials were produced at the North Montana Branch Station at Havre from high quality grade cows and sired by record of performance tested bulls used in cooperation with the U. S. Range Livestock Experiment Station at Miles City. The bulls were mainly from one line of breeding and were used for one breeding season only. A total of 205 steer progeny from 23 sires were tested in the period from 1945 to 1949, inclusive.

The calving season started the last week of March and ended the middle of May. During the summer months cows and calves were grazed on mountain pastures. The summer grazing period ended October 20, when the calves were weaned. The steer calves were then taken to the home station for a six-week fall grazing period prior to the first winter feeding trial. Steer calves used in these feeding trials were selected at random within available progeny groups. When numbers were sufficient, 8 steers from each progeny group were assigned to the trials.

During the five-year period of record of performance testing, treatments for all steers consisted of three feeding periods: first winter feeding period (140 days) on a moderate fattening ration; a summer grazing period on mountain pastures; and a second winter feeding period (112–135 days) on a fattening ration.

During the first winter the calves were given a two-week warm up period when first put in their individual stalls for the winter test. Three-day weights were taken at the beginning and end of the trials. The daily feed per head for this period consisted of 5 lb. of concentrate plus a maintenance allowance of alfalfa hay based on the formula of Brody *et al.* (1934) for body weight. The quantity of hay fed was slightly more than the steers would clean up along with the grain. The concentrates consisted of 45 parts, by weight, of dry rolled barley, 45

parts of dried molasses beet pulp, and 10 parts of soybean oil meal. Salt and bone meal were fed free choice. Ice-free water was provided in tanks. When not in the individual stalls during the regular feeding hours, the steers had access to inside lots for shelter and outside lots for exercise. Weights were taken each 28 days.

After the completion of the first 140-day feeding trial (X_1), the steers were turned out on short grass pastures typical of plains area at the home station for approximately three weeks before being trailed to the mountain pastures for the summer grazing period (X_2). This period usually lasted from June 1 to the latter part of October.

The average annual precipitation on this range covering the grazing months during the five years of this study was 13.2 in., which is 1.4 in. more than the average of the past 23-year period.

The second winter trial (X_3) consisted of a fattening period following a warm-up of about 7 days after the grazing period. The steers were given an 112-day fattening trial with the exception of the last two feeding trials when they were fed 135 and 127 days, respectively. The concentrates consisted of 47 parts dried molasses-beet pulp, 47 parts barley, and 6 parts soybean oil meal. The ratio of roughage to concentrate was controlled individually. During the first 28-day period the steers were fed approximately 3 parts hay to 1 part concentrate. This ratio was gradually reversed until the last (fourth) 28-day period when the steers were fed approximately 1 part hay to 3 parts concentrate. Actually, the steers were not on a heavy fattening ration until the last 28-day period. As a consequence, the daily gain (1.93) obtained for this period was only slightly more than during the first winter period (1.88) when the steers were fed approximately a 2:1 hay concentrate ratio. The steers were fed in open shed lots and provided with ice-free water in tanks. Salt and bone meal were fed free choice.

Results and Discussion

Relationships between the average daily gain during the following three growth periods were examined in this study: (1) first winter in the feedlot (140 days) on a moderate fattening ration, (X_1), (2) second summer on the range, (X_2), and (3) second winter in the feedlot (112–135 days) on a fattening ration, (X_3).

Genetic, phenotypic, and environmental correlations computed by the method developed by Hazel *et al.* (1943) and adapted to beef cattle data by Knapp and Clark (1947) are given in table 1. Tests of significance were not made due to the lack of a valid method. Heritability

TABLE 1. GENETIC, ENVIRONMENTAL, AND PHENOTYPIC CORRELATIONS FOR THREE GROWTH PERIODS

		X_1 First winter	X_2 Second summer	X_3 Second winter
X_1				
First winter	r_G		.45	.99
	r_E		−.14	.19
	r_P		.07	.32
X_2				
Second summer	r_G			.87
	r_E			−.21
	r_P			.02
Heritability		.34	.43	.09

was computed by the method of paternal half-sib correlation. Large sampling errors may occur when the number of sire groups is few. Means of the growth data are given in table 2. Mean squares and cross products are shown in table 3.

X_1 was almost perfectly correlated genetically with X_3 (+0.99) and was highly correlated with X_2 (+0.45). X_2 and X_3 were also very highly correlated (+0.87). Fairly highly heritablity values were found

TABLE 2. SUMMARY OF PERFORMANCE DATA OF STEERS FOR A 5-YEAR PERIOD

First winter-moderate fattening:	1945	1946	1947	1948	1949	Total or average
Length feeding period, days	140	140	140	140	140	140
Initial weight, lb.	430	453	480	498	489	470
Final weight, lb.	707	693	745	761	755	732
Av. daily gain, lb.	1.98	1.71	1.89	1.88	1.95	1.88
Av. daily feed consumed						
Grain, lb.	5.0	5.0	5.0	5.0	5.0	5.0
Hay, lb.	8.4	8.8	9.5	9.0	10.0	9.1
Second summer-on mountain range:						
Length of feeding period, days	139	146	111	138	110	
Initial weight, lb.	660	666	722	685	726	692
Final weight, lb.	918	931	923	887	966	925
Av. daily gain, lb.	1.85	1.82	1.81	1.46	2.18	1.82
Second winter-fattening:						
Length of feeding period, days	112	112	112	135	127	
Initial weight, lb.	913	904	942	886	975	924
Final weight, lb.	1077	1119	1149	1142	1294	1156
Av. daily gain, lb.	1.46	1.92	1.85	1.90	2.51	1.93
Av. daily feed consumed						
Concentrate, lb.	11.7	12.0	14.5	12.8	13.9	13.0
Hay, lb.	6.6	5.9	5.5	7.3	11.4	7.3
No. of progeny	48	49	46	39	23	205
No. of sire groups	5	6	5	4	3	23

for X_1 (0.34) and X_2 (0.43), while X_3 (+0.09) was only slightly heritable.

Gains during the three growth periods seem to be influenced to a large extent by the same block of genes. Genes responsible for growth during the first and second winter periods and for the summer and second winter periods were very similar.

Cattle selected in either winter period should show a definite advantage in the other winter period. Winter gains were fairly highly correlated with gain on summer range. As a consequence, selection in one

TABLE 3. MEAN SQUARES AND CROSS PRODUCTS

Source of variance, d.f.		X_1	X_2	X_3	$X_1 X_2$	$X_1 X_3$	$X_2 X_3$
Among sires	18	.0626	.1094	.1616	.0191	.0478	.0326
Within sires	182	.0359	.0541	.1328	.0016	.0203	−.0020

environment should result in appreciable genetic gain in other environments.

Kidwell (1954) obtained a positive correlation (+0.35) between two winter periods on hay, and a negative correlation (−0.16) between the first winter and subsequent summer gains. In a comparison of yearling gain in steer calves (including a winter and summer period) with gain during a 168-day fattening period, Koger and Knox (1951) obtained correlations of +0.17 within year and sires, and of +0.43 between the averages of sire groups within years. They concluded that a positive relationship exists between gains made at different periods if the environment within periods is similar for different animals.

Fairly high heritability estimates were obtained for the first winter period (0.34) with a limited ration, and for the summer range period (0.43). In contrast, an extremely low estimate (0.09) was found for the second winter period (X_3) with a fattening ration. Several factors could account for the latter extremely low value. First, the older steers may have passed their maximum growth capacity. Second, the duration of the feeding period was considerably shorter than that of other studies reported.

Cattle selected for rapid growth rate under conditions of limited winter fattening would be expected to produce offspring which would gain more rapidly on grass than an unselected population. Likewise, cattle selected under a grass fattening environment would be expected to produce offspring which would gain more rapidly in the feedlot.

The present study indicates that the plane of nutrition on a moderate fattening ration is high enough to identify animals with superior gaining ability. However, if previous estimates of heritibility are correct, this type of feeding program will be much less effective than full feeding in identifying superior genetic seedstock.

In view of the moderately high heritability of gain (0.43) as yearlings on summer range, and of its close association with winter gains, a program for obtaining superior seedstock by selecting under summer grazing conditions may be suggested to the commercial producers who sell yearlings or older cattle off grass in the fall. High estimates of the heritability of final weight in the feedlot, Shelby *et al.* (1955), lend indirect support to a weight-for-age pasture indexing program.

Varying amounts of progress for rapid gaining ability can be made by selecting at the environmental periods studied. Improvement in one period will automatically result in some improvement in the others. The ultimate selection program will be determined by the economics of the situation. Selection of breeding stock is usually done at the earliest possible age.

Summary

The relationships between three successive growth periods in 205 high grade Hereford steer calves from 23 sire groups were studied at the North Montana Branch Station at Havre. The periods were first winter on a moderate fattening ration, second summer on the mountain range, and second winter on a fattening ration. The mean daily gains in pounds for the periods were as follows: first winter, 1.88; second summer on grass, 1.82; and second winter, 1.93.

Winter gains were extremely highly correlated genetically (+0.99). Gains on summer range were highly correlated with first (+0.45) and second winter (+0.87) periods. Selection in any one period should result in some genetic gain in the others. Maximum production would probably be obtained if selections were done in the period and nutritional regime for which the commercial stock were intended.

The following estimates of heritability were obtained by paternal half-sib correlations: first winter on moderate fattening ration, 0.34, second summer on grass, 0.43, and second winter on a fattening ration, 0.09.

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THE MEAT-TYPE STEER: A SYMPOSIUM PRESENTED BEFORE THE ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION IN CHICAGO, ILL., NOVEMBER 23, 1956

INTRODUCTION

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THE few minutes allotted this morning do not permit me to say all of the good things that can and perhaps should be said on occasions of this sort about activities in animal husbandry. I shall assume that mention of these good things may be delayed, however, because I have certain concerns about our future which I should like to present. I should like to present these concerns even though I cannot now document the evidence for the point of view I shall present.

Reference has occasionally been made at these meetings to the importance of art in animal husbandry. In fact it has been implied at times that science, in contrast, although probably having much to contribute, still was not quite to be trusted in the practical field of animal production; almost as though knowledge of the detail of a scientific field and knowledge of the livestock industry were at least partially incompatible.

"The eye of the master fatteneth his cattle" has stood high among the adages we have respected. This adage has been interpreted as the ability of the master to read "sign", the ability to "know" without necessarily knowing how he knows what his animals need for their greatest good. It has implied the ability to evaluate visually and tactilely the different points of an animal, the ability to combine the resulting values, each unexpressed, into an over-all "index" of merit, with each point properly, but unconsciously, weighted according to its ultimate value. It has implied the ability to predict the merit of the whole animal, or of some one or more functions of the animal at a later age and under other conditions. It has implied the ability to predict the details of that animal's carcass after slaughter and after processing. It has gone to the extent, also, of implying the ability to predict what the next

generation will be when the animal is matched in infinite parental combinations. For the possessor of this art to attain the greatest respect as a stockman he must do all of this without resort to mechanical aid or knowledge of measured association. To do otherwise would be to imperil the result. Also, pride in mastery of the art would decline as attempts to reduce it to a science were made.

The art of animal production is found in the relation of the individual husbandman to the individual animal. Science is found in the relation of the husbandman to groups of animals, of which the individual is a respected member. Science can enter also into the relationship between the two as individuals, but only insofar as it takes cognizance of the animal as a representative of a group.

It has been said from this platform within the last decade that it is unlikely that animal husbandry will ever be transformed from an art to a science. Whether or not this is true may be quite immaterial. The real issue is whether the emphasis has been placed wrongly. I believe that animal production can progress only as it is grounded in scientific animal husbandry. We have today an industry with a diminishing labor supply and one that is facing intense competition. Our industry is one that must attain greater efficiency; it must change in the size, organization and scope of its working unit if it is to attain maximal efficiency for mechanization. It is largely if not wholly as we understand the science of groups of animals that the necessary changes will become possible. The individual relationship will of necessity be curtailed, but by the same token, when it does become necessary or possible, it needs to be made to count for the very most that science can accomplish.

I return again to that suspicion of some intangible antagonism between science and animal husbandry as professions. Science need not lead a man away from animal husbandry; it can intensify his interest in the livestock industry. It is only as we build a knowledge of the science of livestock and as our young men have opportunity to observe and to study the science of farm animals directly that this can be realized. A critical review of the contents of our courses and the organization of our curricula is definitely due. Our introductory and our survey courses too often merely borrow from the nutrition, the breeding, the physiology and the meats courses yet to come. Our production courses also may do little but review poorly the courses that precede them. Art, conjecture, and science untested in farm animals, may utilize much of the time given to the courses. The training that will furnish the challenge necessary if good students are to interest them-

selves in animal husbandry and if they are to contribute to it must be forthcoming and steadily strengthened.

Summary of this briefly presented point of view emphasizes the need for reappraisal of two points; first, what is most important in our working concept of professional animal husbandry if we are to help livestock production to take and hold its proper place in our future economy, and second, what should we be trying to teach if we are to attract the kind of young men we need and to prepare them for the task that is ahead.

Our program this morning might be construed as the efforts in one area of animal husbandry to reappraise as to what is known and not known and where we may be going. I have asked our research committee to prepare this program and their efforts have resulted in our symposium this morning.

THE RELATION OF CONFORMATION TO CARCASS TRAITS

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THE commercial beef producer uses the *Official U. S. Standards for Grades of Carcass Beef* as a guide. The feeder selects and feeds cattle with a grade goal in mind. Feeder cattle prices are influenced greatly by the potential carcass grade of the cattle under practical management. The official standards, originally formulated in 1916 and adopted in 1926, have undergone several revisions and were last revised and reprinted with amendments as Service and Regulatory Announcements AMS 99, in June, 1956. Under "Application of Standards", the opening sentences are: "Beef is graded on a composite evaluation of three general grade factors—conformation, finish and quality. These factors are concerned with the proportion of the various wholesale cuts in the carcass, the proportions of lean, fat and bone, and the quality of the meat".

Consumer demand forces a wide spread in price between preferred retail beef cuts and less popular cuts. Comparable price spreads exist among the wholesale cuts yielding preferred retail cuts and those which yield less popular retail cuts. The wholesale loin, rib and round, in that order, are the preferred wholesale cuts. Loin prices in the higher grades of beef may be six or seven times as high as prices for flanks and navels, for instance, while ribs may be four or five times as high, and rounds three or four times as high.

Beef carcasses of the most desirable conformation should have greater than average proportions of the preferred cuts to satisfy one of the objectives of the official grade standards. The official standards state: "Prime grade beef carcasses and wholesale cuts are blocky and compact and very thickly fleshed throughout. Loins and ribs are thick and full. The rounds are plump and the plumpness extends well down toward the hocks. The chucks are thick and the necks and shanks short".

The Texas Agricultural Experiment Station in 1950 began a formal study of the variations in the yield of whoesale cuts of fed steers as part of a beef cattle breeding project. Herefords and first cross Brahman-Herefords have been tested each year, and this year ¼ Hereford ¾ Brahman, ¾ Hereford ¼ Brahman and purebred Brahman

steers were included. The purpose of the carcass studies originally was to identify the type or types which showed a definite increase in carcass value because of a higher yield of preferred cuts. Test steers have shown wide variation in conformation.

Standard cutting procedure followed closely the recommendation of

TABLE 1. SLAUGHTER AND CARCASS CHARACTERISTICS OF SHORT-FED YEARLING HEREFORD AND BRAHMAN×HEREFORD STEERS[a]

Item	Mean values		Probability of chance occurrence
	Hereford	Brahman× Hereford	
Number of steers	59	90	
Slaughter live weight, lb.	743.5	782.2	.001
Chilled carcass weight, lb.	445.7	490.1	.001
Dressing percentage, chilled	59.9	62.6	.001
Area of eye muscle, unadjusted, sq. in.	8.45	9.00	.05
Carcass grade	High good+	High good−	N.S.
Percent hindquarter	49.7	50.2	.01
Percent forequarter	50.3	49.8	.01
Percent rib	8.9	8.9	N.S.
Percent short plate	6.8	6.9	.05
Percent foreshank	4.4	4.2	.001
Percent brisket	4.9	4.8	N.S.
Percent chuck	25.2	24.9	.01
Percent flank	5.6	5.7	N.S.
Percent full loin, trimmed	16.1	15.6	.01
Percent round, rump on	24.7	25.1	N.S.
Percent cushion round	15.4	15.5	.1
Percent high priced cuts (Loin+rib+round, rump on)	48.8	49.9	N.S.
Estimated percent lean in carcass	58.3	58.6	.05
Estimated percent fat in carcass	27.5	26.1	N.S.
Estimated percent bone in carcass	15.4	15.4	N.S.

[a] Summary of data for 1951, 1952, 1953 and 1954.

Cooperative Meat Investigations, as reported by Hankins and Howe (1946) and later adopted by the Reciprocal Meat Conference as illustrated by Wellington (1953). One side of each carcass was cut the first two years, but both sides have since been cut.

Results of the first four years were reported by Butler, Warwick and Cartwright (1956) in a comparison of 59 Hereford and 90 first cross Brahman×Hereford carcasses. The Hereford steers definitely showed more desirable conformation by visual estimates. After adjustment for carcass weight differences, the Herefords averaged about 3 cm. shorter in body and 6 cm. shorter in length of hind leg. Data reported in the paper are repeated in table 1.

In this discussion the differences in conformation are considered without regard to breed. The cut-out data were surprisingly similar. The longer carcasses had a slightly higher percentage of hindquarter and round, rump on. The advantage of round was lost, however, when the comparison was made on "cushion round", or round, rump and shank off, which yields the desired round steak and roasts.

The shorter carcasses had a slight advantage in percentage of full loin and chuck.

Though research workers probably should not have preconceived ideas, the smallness of the differences in beef carcass cut-out have been amazing to me. The carcass of a cutter grade Guernsey steer showed about average cutting figures. Four high prime steers showed about 5% lower yield of the three preferred cuts than high good to low choice steers. Here was a definite clue. Rather fat carcasses cut-out at a distinct disadvantage, and a very poorly shaped carcass with almost no fat showed average cut-out.

Other carcasses showing rather wide variations in fatness yielded a highly significant correlation coefficient of —0.5 between carcass fatness as estimated from 9–10–11 rib cut and cut-out as shown by the combined yield of preferred cuts.

Gallow made detailed studies on carcass composition of cattle, sheep and swine. He concluded in one paper (1949) "that the major changes in anatomy of carcasses and in the chemical composition of their tissues largely depend on the level of fatness of the carcass".

The influence of excessive fatness in lowering the yield of lean cuts of pork has been well recorded, publicized and put to work in grade specifications.

Ham and loin of pork are quite comparable with preferred beef cuts. Present beef cutting methods allow longer rib ends and untrimmed "backfat" on the beef cuts. This reduces the influence of increasing fatness on lowering the yield of loin and rib. The present practice of selling the kidney fat with the carcasses of beef, and leaving a liberal amount of that fat on loin steaks, also probably minimizes the reduced yield of preferred cuts from very fat carcasses. Similar effects of fat deposition in lowering yield in beef and pork carcasses, however, are not too surprising. Other pork carcass concepts, such as length, may apply to beef carcasses. Medium length may be desirable.

After being convinced of the influence of fatness, it was decided to adjust to standard fatness before analyzing differences in cutting percentages. Co-variance methods were used on the data shown in

table 2 from 51 steers slaughtered in May, 1956. These steers were produced under the same management practices at T.A.E.S. Substation No. 23, McGregor, Texas. Management practices are standardized closely each year and as closely as possible between years. The steers were fed a fattening ration in drylot for about 175 days, and slaughtered at about 15 months of age.

Breeds may be disregarded, and differences in shape of carcasses may be studied. Hereford carcasses, of the most desired shape by the standards of today, graded higher and showed a slight advantage in yield of preferred cuts. Fat seems to cause the major variability in cutting yields. Lean and bone seem to develop proportionately over a fairly wide range of carcass shapes.

Area of eye muscle at the twelfth rib cross-section has been used frequently as a measure of carcass muscling. Two adjustments were necessary to make direct comparisons on the ribeye area in carcasses showing as much variability as illustrated in table 2. Carcass weight had a negative influence. The simple expedient of comparing area of eye muscle (sq. in.) per cwt. of carcass was inadequate. Heavier carcasses were at a distinct disadvantage. Increasing fatness, as measured by thickness over the eye muscle, also had a negative effect.

An equation was developed to adjust to a standard carcass weight and fat thickness. For 500 lb. carcasses with 10 mm. average fat thickness over the "eye" muscle, the equation was as follows:

$$Ya=Y-[.00053448\ (X_1-10)+(-.0045605)\ (X_2-250)]$$

which simplifies to $Ya=Y-.00053448X_1+.0045605X_2-1.134780$

Where X_1=fat thickness

and X_2=side weight

Values obtained by this formula were (sq. inches of eye muscle per cwt. of chilled carcass—adjusted)

Hereford	¾ Hereford ¼ Brahman	½ Hereford ½ Brahman	¼ Hereford ¾ Brahman	Brahman
1.83	1.85	1.75	1.66	1.80

Analysis of variances indicated .05 level of significance for mean differences.

Wholesale cut separations are based primarily on skeletal check points. If bones develop proportionately, the skeleton should be divided proportionately. If muscles develop proportionately, they should be separated proportionately because muscle locations are fixed in relation

TABLE 2. CARCASS CHARACTERISTICS OF YEARLING STEERS

Item	Hereford	¾ Hereford ¼ Brahman	½ Hereford ½ Brahman	¼ Hereford ¾ Brahman	Brahman	Probability of chance occurrence
Number of steers	9	8	12	12	10	
Chilled carcass weight, lb.	521.5	507.6	550.5	482.0	402.6	
Carcass weight per day of age	1.16	1.13	1.25	1.10	0.91	.01
Dressing percentage	60.1	59.3	60.9	60.1	59.1	N.S.
Adjusted length of body (cm.) [a]	113.9	115.6	115.6	118.5	115.4	N.S.
Adjusted length of leg (cm.)	71.5	74.0	76.1	79.1	77.4	.01
Adjusted width of shoulder (cm.)	20.1	19.3	19.0	18.3	18.4	.01
Adjusted width of round (cm.)	21.5	21.4	21.3	21.5	21.3	N.S.
Carcass grade	High good+	Av. good	Av. good	High std.—	High std.—	.01
Percent rib, adjusted [b]	9.1	8.6	8.8	8.7	9.2	.01
Percent full loin, adjusted	15.2	15.2	14.9	14.8	15.1	N.S.
Percent round, rump off, adjusted	21.7	21.4	21.4	22.0	22.0	.05
Percent hind shank, adjusted	4.3	4.7	4.5	5.4	5.3	.01
Percent cushion round, adjusted	16.9	16.5	16.6	17.0	17.3	N.S.
Percent loin, rib, round, adjusted	50.3	49.3	49.2	49.6	50.2	.01
Percent fat	31.7	25.6	27.8	20.2	19.3	.01

[a] Body measurements adjusted to mean carcass weight.
[b] Cut-out percentages adjusted to mean percent fat in carcass as estimated from 9–10–11 rib cut.

to bones. The tibia, femur, the six lumbar vertebrae, and humerus bones were measured to check proportionate bone lengths. The short loin length is determined by the lumbar vertebrae and the "cushion round" length by the femur. The relative length of those two bones was of most interest. Femur length divided by length of the six lumbar vertebrae gave mean ratios of:

Hereford	¾ Hereford ¼ Brahman	½ Hereford ½ Brahman	¼ Hereford ¾ Brahman	Brahman
0.99	1.01	1.03	1.05	1.06

Mean differences were highly significant. This ratio explains, at least partially, the longer-legged appearance of the steers carrying Brahman blood. Increased length of leg without proportionately increased percentage of round obviously would give a round less thick and plump. The purchaser of a round steak is likely, however, to be indifferent about the shape of the round from which it came. Thickness, plumpness and muscling of loin and rib cuts likely would be of much greater concern to him.

The main conclusion reached from carcass studies in the Meats Laboratory of the Texas Agricultural Experiment Station is that the animal breeder has considerable latitude in selecting animals of different shapes without encountering great changes in the proportion of wholesale cuts. This does not discount the salability of good conformation by present standards. The cattle breeder, however, should give increased emphasis to production efficiency. Carcass shape may become even less important to consumers if closely trimmed, boneless retail cuts become more popular, as appears likely.

A recent quotation from Dr. John Hammond (1955), eminent worldwide authority on meat animals, from a speech reported in the Journal of the Farmer's Club seems appropriate: "I quite agree . . . that the modern beef animal is getting too short; it has, therefore, too great a depth of rib. It is only the top line that is valuable. The depth, the lower part of the ribs, is low priced."

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RESULTS OF CONSUMER PREFERENCE STUDIES

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THE problem of providing consumers with the quality of beef they prefer has been recognized by workers in many different areas. Some of our most vivid memories are associated with the disappointments we have encountered. We seem to remember in general the goodness of meat but the disappointments we recall in more detail.

Much consumer preference has been inferred from laboratory panel observations with the implication that those consumers who disagree are misinformed or ignorant. The laboratory panel is concerned with attributes as may be determined by sensory taste tests. This is in contrast with surveys of attitudes or opinions. Sensory tests are used to determine discrimination or preference. If there are no discernible differences there can be no preferences. The foregoing should not be construed to mean that laboratory and survey methods are incompatible.

The function of consumer education is not to determine preference or likewise question consumers preference if they are not in agreement with various standards of acceptability. Standards are of value in consumer education if they assist the purchaser in knowing the range of choice and if they assist consumers in obtaining their preferences intelligently and economically. Likewise there are certain advantages from the merchandising standpoint in selling the consumer beef she prefers rather than in trying to "educate" her.

Moulton (1928) wrote: "When it comes to the selection of meat the average consumer is not so well situated. He does not know, in many cases, the relation between the amount and distribution of fat and the quality of the meat. He probably cannot select a piece of meat that is sure to be sufficiently tender to suit his demands. This is not surpris-

[1] Series Paper No. 1698 approved by the Director of the Missouri Agricultural Experiment Station.

ing, since beef experts have trouble in consistently selecting beef that will turn out tender. But the average consumer does know when meat is too fat for him, for there is a very marked tendency for him to select the leaner meats and cuts from the lighter carcasses".

Watkins (1946) in the same publication emphasized differences in preference. He classified the variation in preferences into two categories (1) national tastes and (2) tastes resulting from economic necessity. He pointed out that many, if not most consumers do not like fat beef even though they can easily afford it. Some consumers prefer the fatter beef but buy the more economical source of lean. Others are concerned about the health or esthetic aspects. There are, however, some consumers who like fat beef. For many of them, cost is not an important factor. These connoisseurs will, no doubt, continue to be well cared for.

Gardner and Adams (1926) reported on preferences for beef. By rather questionable procedures the authors concluded that consumers preferred the higher grades.

Ashby *et al.* (1941) reported on consumer attitudes as obtained from 351 schedules. Two thirds wanted a small amount of fat and one fourth a goodly amount. There were some indications that higher income groups preferred a greater degree of finish than the lower income group.

In the two fore mentioned surveys the largest group thought they bought the very best grade, presumaby Prime or Choice.

Liston (1937) reported the belief of meat retailers to be that most household buyers made few specifications about their purchases and, that they usually indicated the use to be made of the cut and relied on the meat retailer to choose the cut that would satisfy their requirements. More recent surveys indicate this is also true today in service stores.

Caso (1951) after surveying meat retailers in the Baton Rouge area, concluded from them that about 20% of the consumers were aware of quality factors in meat and there was a modal preference for less highly-finished grades. He also concluded that a low level of knowledge was not necessarily associated with a low level of satisfaction.

Sloop *et al.* (1952) reported important factors influencing consumer selection of meats in the St. Louis area to be: 1, proportion of fat to lean; 2, attractiveness; 3, color of lean, and 4, price.

One of the first sales test where side by side comparisons were made was reported by Meyer *et al.* (1952). Compared were chuck pot roasts and short loin steaks from Choice, Good and Commercial grades. The

TABLE 1. WASHINGTON STATE COLLEGE SALES TEST WITH POT ROAST AND T-BONE STEAKS

(Priced identically)

Cut	Preference, percent		
	Choice	Good	Commercial
Pot roasts	23.2	39.3	37.5
T-bone steaks	29.5	30.0	40.5

grades were priced identically and sold in four metropolitan area stores. The percentages of each grade sold are indicated in table 1.

The conclusion that consumers prefer commercial is somewhat misleading. It is apparent that some consumers preferred each grade. (Here the assumption is that the differences were knowledgeable.) There was also no indication of "No preferences" purchasers. There was, however, a surprisingly high preference for the lower grades and one can hardly quarrel with their generalization that, "Consumers showed a decided preference for lean beef". It should be emphasized that this was a visual preference approach. In another test where each grade was priced at about O.P.S. ceiling some interesting results were obtained. Here the preferences were as shown in table 2.

The foregoing indicates that price differentials resulted in some additional preference for the lower priced grades.

Lasley *et al.* (1955) reported on a pilot scale sales test where each grade was priced identically. (See table 3.) A follow up on this sales test indicated that most consumers were well satisfied. The dissatisfaction which did exist centered mainly on the lack of tenderness with the lower grade steaks and the excess fat of the higher grade cuts, especially the roasts. One might generalize that the range of satisfactions for consumers is in the aggregate considerably wider than many consider it to be.

TABLE 2. WASHINGTON STATE COLLEGE SALES TEST WITH POT ROAST AND T-BONE STEAKS

(Priced at O.P.S. ceiling)

Cut	Preference, percent		
	Choice	Good	Commercial
Pot roast	23.4	31.1	45.5
T-bone steaks	16.0	30.0	54.0

TABLE 3. UNIVERSITY OF MISSOURI PILOT STUDY SALES TEST WITH RIB ROASTS AND RIB STEAKS

(Priced identically)

		Preference, percent		
Cut	Prime	Choice	Good	Commercial
Rib roasts	10.7	26.7	30.7	31.9
Rib steaks	7.7	21.5	27.7	43.1

Rhodes *et al.* (1955) reported a study in which 1500 respondents were surveyed in the St. Louis area. Visual preferences taken in stores (not in sales tests) on preferences for roasts and steaks are shown in table 4.

There was evidence that the grading system was not effective when used as a hedonic scale to measure eating satisfaction. The fore mentioned results differ from those given in table 3 and from the results reported by Branson in 1956 for Houston, Phoenix and Denver shown in table 5.

It should be born in mind, however, that each of these tests were run under somewhat different conditions, i.e., a sales test, interviews using the product and interviews using pictures. In each case what was involved was a visual appraisal and not an eating (sensory) appraisal. With regard to this matter, it is almost a maxim to say, that "We eat

TABLE 4. PERCENTAGE DISTRIBUTION OF FIRST PREFERENCE RANKING OF GRADES OF ROASTS AND STEAKS BY INCOME GROUPS

	Income level		
Grade	Upper	Middle	Lower
	%	%	%
		Roasts	
Commercial	14.4	17.4	23.2
Good	28.8	37.2	28.7
Choice	23.0	19.8	23.2
Prime	33.8	25.6	24.9
		Steaks	
Commercial	14.1	24.3	12.8
Good	21.4	30.4	20.3
Choice	25.8	20.3	33.2
Prime	38.7	25.0	33.7

TABLE 5. BEEF GRADE PREFERENCE OF CONSUMERS

Grade	Percent of families in		
	Houston	Phoenix	Denver
Prime	13		
Choice	24	32	32
Good	43	41	47
Commercial	18	27	21
No preference	2		
Total	100	100	100
Number of families	987	491	500

with our eyes" but perhaps equally true, "The proof is in the pudding". It is an obvious truism that there were preferences for all of the grades displayed.

In discussing the socio-economic relationships it is difficult to evaluate the inter-relationship effects, i.e., income, education, race, and sectional influences. This may be noted in tables 6 and 7. While the preferences were greater for the higher grades in the St. Louis study it will be noted in both studies (see tables 6 and 7) that of those who did prefer Prime the largest perceptage was found among those with a college education. Similarly in the Houston study, the greatest preference for Prime was with the highest income group.

Of considerable interest is the results from the St. Louis study on the influence of sex. It will be noted in table 8 that there is a tendency for the males to prefer the higher grades and the females the lower grades. This was also true not only for the whites but also Negroes. In neither the Houston nor St. Louis studies is there sufficient data to suggest that there was a difference in preferences between whites and Negroes.

This paper is not intended as a comprehensive review of all of the

TABLE 6. PERCENTAGE DISTRIBUTION OF FIRST PREFERENCE RANKINGS OF GRADES OF STEAK BY 250 MIDDLE INCOME RESPONDENTS OF THREE EDUCATIONAL LEVELS

Years of schooling	Commercial	Good	Choice	Prime	Total
	%	%	%	%	%
8 years or less	16.2	16.2	26.6	41.0	100
9 to 12 years	13.7	20.4	34.8	31.1	100
13 years or more	10.0	27.5	27.5	35.0	100

TABLE 7. EDUCATION OF THE HOUSEWIFE IN RELATION TO BEEF GRADE PREFERENCES

Houston, Texas, 1955

Beef grade preference	Percent of families		
	Grade school	High school	College
Prime	12	11	21
Choice	23	21	31
Good	43	48	34
Commercial	18	20	12
No preference	4		2
Total	100	100	100
Number of families	282	504	190

beef consumer preference work but rather to indicate the general nature and results. Very significant research contributions have been made by the American Meat Institute Foundation and the Quartermaster Food and Container Institute as well as other state experiment stations.

In any discussion of consumer preference it should be appreciated that in the case of meat products that a greater percentage of the consumer food dollar is received by the producer than is the case for most other food products. It is no secret that consumers have been willing to pay the price necessary to satisfy their demands. The contributions that the producer, processor and retailer have made, bear a relation to the share of the consumers' meat dollar that each has received. It should be emphasized that there is a strong trend for meats to follow other food products with an increasing amount of "built in maid service". The extra costs are passed on to the consumer thus reducing the producers share of the consumers dollar.

Along with the greater amount of built in convenience, consumers are also demanding: 1, Attractivesness in packaging and display; 2,

TABLE 8. PERCENTAGE DISTRIBUTION OF FIRST PREFERENCE RANKINGS OF ROAST GRADES BY SEX OF RESPONDENT

Sex	Commercial	Good	Choice	Prime	Total
	%	%	%	%	%
Female	21.2	32.6	20.0	26.2	100
Male	10.5	27.2	28.9	33.3	100

Cleanliness and nutritional safety; 3, Variety available throughout the year; and 4, Optimum quality with price as an important consideration.

Conclusions

Most consumers know very little about beef quality or grades. There is a high degree of acceptability of beef grading U. S. Good. This grade is not available in a very large proportion of super markets although changes in this direction are currently taking place.

Most consumer dissatisfaction with beef relates to tenderness. With beef from older animals there is need for the development of more effective tenderizing procedures especially for use at the processor level.

Consumers generally have an aversion to fat. Many have described consumers as wanting an impossible combination of leanness, juiciness, tenderness and flavor. Admittedly, this is difficult to accomplish but it is not at all impossible.

Consumers generally do not wish to eat fat because they believe this may well result in a plumper figure and a shorter life, both of which are undesirable to them.

In conclusion the beef industry must be adaptive in meeting the changing and more critical demands as we move further from the bare essentials of living to one of increasing abundance. Nutritional and esthetic factors will probably be of even greater importance to consumers than presently. Since it is the producer who primarily determines what will be inside the hide it is with him especially that we need to counsel and take stock.

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THE INTERRELATIONS OF TYPE, PERFORMANCE, AND CARCASS CHARACTERISTICS

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ALL work reported here was done with Hereford cattle. In some cases comparisons were between comprest and conventional types, in others between selection within the conventional type. The former provided greater contrasts, the latter may have had the advantage of fewer genetic differences not related to type. In addition to his colleagues, the writer is indebted to numerous workers for unpublished information not included in the list of references.

We will start by explaining some of the terms to be used. I know of no field of investigation where words have so many different meanings. Such confusion among workers results in added misunderstanding among stockmen where misunderstanding is the rule rather than the exception. When some report type unrelated to production but closely related to carcass excellence and others that type is an important factor in production with little influence on the carcass, clearly they are talking of different things. In the first case they must be speaking of characteristics of form unrelated to size; in the second case, of factors which have important influence on size. Without attempting to argue the merits of the case, we will state that type is used here to distinguish differences in height and length with the term "compact" used to describe animals which are short and low without regard to details of conformation such as; smoothness, width of back, or depth of quarter, traits which animals may possess regardless of type.

Early maturity is a term which may have several legitimate meanings when applied to livestock. With meat animals it usually refers to the age at which they reach market weight and condition. We shall

use the term to describe the ability to fatten quickly or at an early age. Early maturity has been used to describe animals which fatten at light weights. We believe this is a misuse unless the animals are also young. There should be little question of the proper use of the word efficiency. Unfortunately this is not true. If we accept feed required for a pound of gain without reference to composition of the gain; weight of calves produced and gains of young cattle on pasture without regard to the amount of forage eaten, determination of efficiency will be simple. If we seek answers to these questions our procedures will be more complicated and the outcome more in doubt.

TABLE 1. THE EFFECT OF TYPE ON EARLY MATURITY AS INDICATED BY CARCASS GRADES AND YIELDS FOR CATTLE FED AN EQUAL LENGTH OF TIME

Source	No.	Compact		Medium		Large	
		Yield	Carcass grade[a]	Yield	Carcass grade	Yield	Carcass grade
		%					
Hereford assoc.	234	58.6	5.2 Small	58.9	4.9	58.3	5.5
N.M. yrlings.[b]	350	57.4	2.1	57.7	2.1	58.4	2.1 Rangy
N.M. calves[c]	116	58.3	2.5			58.7	2.1

[a] One equals choice and 5 equals low good.
[b] Yield calculated from feed lot weights.
[c] Rib fat thickness for 28 large and 30 compact was 9.9 and 8.0, respectively.

We will start by discussing the relationship of type to production in the fattening phase. Three plans of investigation are used. The first of these is to fatten animals to a fixed weight. The second plan is to fatten individual animals to a stated grade or degree of condition. The third is to feed test groups an equal length of time. Before developing this subject further, we will try to throw some light on the cloudy subject of early maturity. Few experiments show actual measurements of fatness. Several show the carcass grade of animals fed the same length of time and others the time required to reach a fixed grade. For this purpose the experiment sponsored by the Hereford Association (Weber, 1951) is one of the best because of the numbers involved and the care in selecting the test animals.

These data (table 1) show no evidence that compact steers fatten more quickly than those of large type. This is true especially if compactness improves carcass grade or yield of which there is considerable doubt. However, it is only fair to state in a large number of correlations at the Colorado station comprest steers were found to reach low choice grade at a slightly younger age and with a little less time on feed than

conventional type steers. This may be due to a difference in cattle or to the fact that length of feeding was determined by live animal grade rather than carcass grade. In the literature reviewed compact steers graded a little higher alive but no higher in the carcass. If this were true of the Colorado cattle, the comprest steers may have been slightly less fat when taken off feed accounting for a little shorter feeding period.

If we conclude after considering all the evidence that type does not effect quickness of fattening, we may assume that feeding to a fixed condition or for a fixed time are comparable, for in both cases the groups are similar in condition when feeding ends. Kleiber (1936) states that gain and relative feed intake are sound indices of efficiency provided the composition of gain is equal. This is the case when comparing groups where an equal rate of fattening has been demonstrated. It may not be true in comparing individuals or sire groups where there may be important differences in rate of fattening. We may conclude that early maturity is a characteristic of "good doing" cattle regardless of type and not a trait of any particular type.

Now we will return and consider the effect of type on feeding efficiency for there are only two plans to consider. One feeds to a constant weight in which case the larger, faster growing animals will be younger but not as fat when they reach the weight. The other feeds to a uniform condition either by removing individuals as they attain the desired condition or by feeding groups of the same sex and similar initial condition an equal length of time. In both the latter cases the composition of gain will be similar.

When cattle are fed to a standard weight under similar conditions, animals of the large type will make cheaper gains because they will not be as fat. Excellent data are available for such comparisons. Black and Knapp (1936) reported high correlation of economy of gain in the fattening period to ultimate size (rate of gain from birth to slaughter) when steers were fed to a fixed weight of 900 lb. This work establishes a fact of great economic importance but may be questioned as a test of efficiency of energy conversion. Kleiber (1936) treats this point by stating that absolute rate of gain can be used as an index of efficiency only in comparing animals of similar potential size. Which is another way of saying that animals of potentially different size can not be compared in efficiency of feed utilization by the amount of feed required per lb. of gain at any fixed weight. The small type animal being older and fatter will be at a disadvantage because of higher energy content of the gain being made. In contrast to the results referred to above

unpublished data from Stonaker show no correlation between cost of gain and compactness on one hand or wither height on the other when cattle were slaughtered at low choice grade regardless of weight. The data in table 2 comparing types fed an equal time verify these results.

A small but non-significant advantage for compact calves in New Mexico experiments may be accounted for by the slightly higher condition of the calves indicated by the thickness of rib fat referred to previously (Blackwell and Cobb, 1956). Frequent statements that

TABLE 2. THE EFFECT OF TYPE ON TOTAL DIGESTIBLE NUTRIENTS REQUIRED FOR 100 LB. OF GAIN IN FATTENING STEERS

Source	Age	Compact	Medium	Large
		lb.	lb.	lb.
Hereford assoc.	Calves	574	569	568
Hereford assoc.	Yearlings	694	683	709
	Average	634	626	638
New Mexico	Calves	500		523

compact cattle are best suited for fattening at young ages are not borne out in the Hereford Association experiment. Although differences were not significant the big cattle had slightly higher feed costs as yearlings while the compact had higher feed requirements as calves.

Before taking up the effect of type on breeding efficiency the questions of feed consumption and maintenance requirements should be considered. These factors are seldom measured in pasture experiments, therefore it is important to relate them to some measurable character before attempting to evaluate efficiency of pasture cattle. In all feeding tests reviewed feed consumption has been closely related to size. In a Colorado wintering test large, medium, and comprest heifers consumed 23, 25, and 26 lb. of hay daily per 1000 lb. of live weight (Stonaker *et al.*, 1952). The authors reported no significant relationship of type to feed consumed per unit of weight. In New Mexico fattening trials large calves at 22 lb. of dry matter daily per 100 lb. of live weight and compact calves 22.4 lb. (Blackwell and Cobb, 1956). It seemed possible that the same relationship of weight to feed consumption might not exist on the range where the amount eaten may depend on the ability to gather feed rather than the capacity to consume it. It is difficult to measure the amount of forage eaten on large range pastures. At the New Mexico station (Knox, 1956) lignin voided by range cattle was

used as a measure of relative feed consumption. The results are shown in table 3.

The collections were made periodically over several years using comparable groups of cows or heifers run together in a large range pasture. That feed consumption by cattle of the two types is directly in proportion to weights both on the range and in the feed lot appears to have been established. This knowledge makes possible comparisons of efficiency where feed consumed can not be measured.

TABLE 3. LIGNIN VOIDED BY TWO TYPES OF RANGE CATTLE

Type	Compact	Large
Weight of cattle, lb.	750	882
Average lignin voided, lb.[a]	.241	.285
Average lignin voided, lb. per 1000 lb. live weight	.322	.323

[a] In 4-hour collection periods.

Maintenance requirement remains to be considered. It has been established in feeding experiments that rate of gain and feed consumption both are in proportion to weight. If this is true the conclusion that maintenance is also in proportion to weight is warranted. Otherwise ratios of gain to feed eaten would be altered. The question of maintenance requirement of the two types has been confused by the theory that it is related to body surface more than weight. Some have reasoned that this would result in lower requirements for compact cattle because of their form and others that the advantage would be in favor of the larger cattle with greater weight per unit of surface. For some time our people at New Mexico have been measuring area of hides removed from cattle which had been weighed and rated on type prior to slaughter. Both type and weight were related to surface area and tended to compensate each other. Compact animals tend to have a smaller area per unit of weight because they are compact but a greater area per unit of weight because they are smaller. From this information it seems that animals which are similar in age and condition have maintenance requirements approximately in proportion to weight. If this is true of both feed consumption and maintenance requirement, we are in a position to make fairly sound comparisons of range cattle. It is not enough that large cattle produce more than small ones. They must produce more in proportion to their size before a basic difference in efficiency can be established. This does not mean there are no economic advantages for larger cattle irrespective of efficiency of feed utilization. There are

numerous costs which are the same regardless of size and therefore less per unit of production for the larger animals. However, the factor of greatest interest to the producer and the public is the efficiency with which our feed supply is converted into beef.

For some ten years the New Mexico station has compared the two types under range conditions. Herds were set up by selecting cows for compactness and grade on one hand and size or weight on the other. These were chosen as economic opposites. In both cases physical opposites seem impractical as bases for selection. The physical opposite of large is small and of compact is rangy. These would not be used in

TABLE 4. RELATIONSHIP OF PRODUCTION TO WEIGHT OF RANGE COWS

Type	Compact	Large
Cow weight, lb.	934[a]	1066[a]
Calf wt., lb.	417	469
Calf. wt. produced for 1000 lb. wt. of dam, lb.	448	440
Percent of cows which weaned calves	81.6	93.8
Av. annual production per cow, lb.	340	440
Av. annual production for 1000 lb. of dam, lb.	366	413

[a] Weights when calves were weaned.

practice except to gain related or supposed related advantages, which would be superior form in one case and greater weight in the other. Grade was included in selecting the compact herd to avoid inferior animals which might meet a simple requirement for compactness. Bulls and replacement heifers were selected in the same manner.

The production records for these herds are shown in table 4 for the years 1947 to 1951 inclusive. This was a period of below average rainfall although less severe than the years following. These years were used because in 1951 a plan of crossing the types was started which made comparisons of this kind difficult.

The average weight of calves at weaning was greater for the large cows but when this is related to weight of cows and therefore feed consumption the difference disappears. As was true in the feed lot, type had no effect on conversion of energy in the individual animal. The number of calves produced is the factor which reveals a real difference in efficiency. When this is combined with weight of calves the result is a difference in average calf production of 30% in favor of the large cows. When allowance is made for difference in size this advantage is reduced to 13%; still a major advantage to result from one simple difference

in selection. Some explanation for this difference may be found in table 5 which contains lifetime production records of all cows removed from these herds for any reason.

In the past ten years while these records were being taken the average annual rainfall on the experimental range was 6.5 in. In seven years a protein supplement was fed about 90 days in the spring. Two years no feeding was done and in 1954 concentrates were fed until August. Twenty-five of the large cows and only nine of the compact

TABLE 5. LIFETIME PRODUCTION OF RANGE COWS

Type	Compact	Large
Number of cows	80	71
Av. age removed from herd	7.1	8.0
Av. percentage of cows calving yearly	81.6	96.8
Av. percentage of cows weaning calves yearly	75.2	92.5
Av. weight of calves, lb.	374	401
Av. lifetime production, lb.	1442	2170

cows remained in the herd to the end of their tenth year. Regardless of comparative figures, selection for weight as practiced in the large group was highly effective. You may wonder why this surprising difference exists. It seems to those working with the cattle that it is not due primarily to body shape but to the method of selection. Certainly here is a case of vigor and adaptation to a rather rigorous environment. These traits are demonstrated best by growth of young animals, rate of reproduction and longevity. Only one of these can be appraised at an early age when selection must be done. If young cattle are selected for weight for age under a natural environment the other traits may be expected to follow as was the case in this experiment. The question may be asked if these differences would exist under more favorable conditions. This is a subject for further experimentation. It is our present opinion that animals which respond best to any environment are best suited to that environment. We can not expect to develop cattle specially well suited to specific environments or plans of production unless we select breeding animals which respond best to those conditions. Before leaving this subject comment should be made on a commonly held idea that compact cows are poor mothers. In this experiment no more calving trouble was experienced than with the large cows. Average milk production seemed to be as closely related to size as are growth and feed consumption. The small cows nourished their small calves as well

as the large cows did their larger calves. Oklahoma also reports that comprest cows are excellent mothers (Chambers *et al.* 1954).

I have been asked to say something about carcass characteristics. In order to prevent duplication and avoid becoming deeply involved in a subject I know little about, I shall treat the matter in general terms.

In a review of numerous experiments no substantial evidence was found that compactness of type improves carcass grade. Department of Agriculture workers (Woodward *et al.*, 1954) report long bodied steers produce as desirable carcasses as short bodied steers. The word "compact" is used to describe the the higher grades of carcass beef. It seems this factor either receives little attention from the grader or the word has a different meaning than when applied to live animals. There are some grounds to believe the term has more the meaning of meatiness than shortness in beef grading. Most cut-out work shows a higher percentage of round and chuck and a lower percentage of rib and loin from cattle of the compact type. Whether this is an advantage to the butcher depends on whether the rib is given a higher price than the round as in the hotel trade or the round is priced higher as in the butcher shops of our small town. In the Colorado study previously referred to, length of body and hip were found to increase the return from the sale of the wholesale cuts. Bogart states that differences between the lower grades of live animals influence carcass grades more than similar differences in the higher grades. This is in line with our experiment. Given animals of good conformation, carcass grade is determined mostly by condition and factors such as marbling, color, and texture which can be judged little, if at all, in the live animal.

In order to provide the kind of beef the public wants with economy for all concerned from the feeder through the butcher to the consumer we must find a way to produce the desired quality without the wasteful fat too often found. This may be done by breeding, but the methods are not easy and progress may be slow. It seems to the writer something can be accomplished most quickly with quality cattle that grow fast and reach the desired weight at an early age when less fatness is required to meet grade standards. Such beef may not satisfy completely the taste of the gourmand but it will supply the tenderness and flavor sought by the general public and please those seeking the low calorie diet.

Summary

All is not known on this subject. There is much yet to be learned. Some things reported in this paper need verification by other workers

and under other conditions. There are a number of places where we can find general agreement. One is that breeding for short legs and short bodies limits the size of the cattle. When carried to the extreme small cattle will result. Type as it is considered here does not effect the efficiency of energy conversion either in the feed lot or on the range. Compactness of form does not result in the early maturity and increased carcass excellence frequently credited to it. Some compact cattle possess these traits but they are found as often in cattle with more scale. The only advantage which has been established for the compact type is the ability to fatten at lighter weights.

Large type cattle have distinct advantages. Numerous costs of cattle production are fixed per head regardless of size and become less when spread over the greater production of large cattle. Taxes, veterinary charges, and bull service are a few of these. Beef may be produced more cheaply by rapid growing cattle which reach the desired weight at younger ages when less feed is required per unit of gain. Such cattle seem most likely to produce the kind of beef in demand at this time. Although the results require verification, the thing of most interest to us is the possibility of obtaining more productive breeding cattle which are better suited to their environment by selecting young animals with greater weight for age in that environment.

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A SUMMARY OF THE MINUTES OF THE FORTY-EIGHTH BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

W. M. BEESON, *Secretary*
Purdue University

The meeting was called to order in the Louis XVI Room of the Hotel Sherman, Chicago, Illinois, on November 24, 1956, at 2:15 p.m. by President L. E. Casida. The minutes of the 1955 Business Meeting were not read but were approved as published in the Journal of Animal Science, Vol. 15, pp. 322–332.

The report of the Secretary (W. M. Beeson) was as follows:

"The American Society of Animal Production continues to grow in size with a total of 1611 members which is an increase of 102 members over 1955. Members of the Society are scattered throughout the world with the following distribution: United States and Canada, 1,558 and Foreign, 53. The Membership Committee has done an excellent job of encouraging young men engaged in the Animal Sciences to join the Society. Through the work of the committee, 160 new members have been accepted by the Society this year. According to our records, there are still quite a few people who attend the Annual Meeting that are not members of the Society but are eligible for membership. Also, a few individuals who are co-authors of papers are not members.

"Subscriptions to the Journal of Animal Science have increased (74 more) with a total of 1210. In this total, 492 were domestic and 718 foreign. Foreign subscriptions are increasing each year, and it is of special interest that the Journal is sent to 50 different foreign countries. Journals are being mailed quarterly to 2,821 individuals, libraries and business firms. Address changes should be sent promptly to the office of the Secretary to avoid delay in receiving the current issue of the Journal. Address changes are made the first of each month.

"During the year the office of the Secretary has sent three form letters to the entire membership and has mailed two letters to each subscriber. In response, we have received about 4,500 letters plus the usual correspondence necessary in the conduct of the business concerning the Society and the Journal.

"There were 241 papers submitted and 175 were presented on the program, and the remainder (66 papers) were listed by title. Starting the sectional meetings in Breeding and Genetics, Nutrition and Physiology on Friday morning has permitted 21 more papers to be presented.

"As Business Manager for the Journal, I wish to express my appreciation to our Editor, J. K. Loosli, and to the Boyd Printing Company for their promptness and fine quality of work.

"The officers, the various committees and the contributors of papers are to be commended for submitting their material on time and for the preparation of an excellent program.

"At the termination of my three years as Secretary of this Society, I want to express my sincere appreciation to the officers and members of the Society for their fine support and prompt action on business concerning the Society. I have

never worked with an organization or group of people that are more devoted, helpful and interested in building a better Society.

"Also, I should like to thank my secretary, Miss Mary Sutton, for the many hours of office work she has devoted to correspondence and detailed records of the Society for the past three years".

The Treasurer and Business Manager of the Society, W. M. Beeson, presented the following report:

"The balance for the General Society Fund shows an operating gain of $5,328.92 for the fiscal year ending October 31, 1956. This year's net gain in the General Fund was more than last year by $575.57, which was primarily due to the increase in sales of reprints from the Journal.

"Operating expenses for the Society are increasing each year. The total General Fund expenses for this year were $25,604.66 as compared to $22,179.07 for last year. The total income for the General Fund was $30,933.58. The income from the Morrison Award Fund was $1,866.58 and expenditures amounted to $1,543.91, showing a net gain of $322.67.

"The cash balance on hand in the General Fund ($21,644.65) plus the Morrison Award Fund ($3,646.49) at the close of this fiscal year was $25,291.14. In addition, the Society has assets of $18,212.40 in U. S. Government Bonds—Series G, F and J. Thus, the total tangible assets of the Society as of October 31, 1956, were $43,503.54.

"As Treasurer and Business Manager of the Society for three years, I want to thank each member for his fine cooperation in prompt payment of dues, arranging for reprint payments and for accurate notification of changes of address".

Audit of the financial records of the Society for the period November 1, 1955 to October 31, 1956 was made by a Certified Public Accountant, C. D. D'Aoust, Suite 24, Lafayette Loan and Trust Building, Lafayette, Indiana.

President L. E. Casida read part of the auditing report and stated that the detailed records are on file in the Treasurer's office for examination. In part the report was as follows:

"Cash on deposit in banks at October 31, 1956 was reconciled with the balances shown by the bank statement and savings account pass book, which amounts were further confirmed by direct communication with the respective depositaries. The United States Government securities were inspected and counted on October 31, 1956.

"In our opinion, the accompanying statement of assets and liabilities and the related statements of income and expense, and fund balance and net worth present fairly the recorded financial position of American Society of Animal Production at October 31, 1956 and the results of its operations for the year ended October 31, 1956".—signed C. D. D'Aoust.

The Editor of the Journal of Animal Science, J. K. Loosli, gave the following report:

"The Society published 138 scientific papers and 241 abstracts of papers in Volume 15 of the Journal of Animal Science. The 1,316 pages of the volume also included proceedings of the 1955 Annual Meeting, author and subject indexes and a News and Notes section in each of the four issues.

"A total of 153 papers was received during the past year. Of these 106 have been published or are now at the printers for the February issue. Ten are being revised by the authors, 15 are in the hands of reviewers and 22 (14%) were rejected.

"The terms of L. E. Harris and R. W. Bray expire on December 31, 1956 and the Executive Committee has appointed L. J. Bratzler and G. P. Lofgreen to replace them on the Editorial Board.

"Your Editor expresses his sincerest thanks to the Associate Editor, W. D. Gallup, to members of the Editorial Board, and to certain other members of the Society for their invaluable services in reviewing papers. It is only through the prompt and painstaking work of the Editorial Board that it is possible to keep abreast of the big job of publication for the Society".

The records of the Business Manager of the Journal of Animal Science listed the following back numbers of the Journal and Proceedings available for sale on November 1, 1956.

JOURNAL OF ANIMAL SCIENCE

Vol.	Year	Complete volumes	Number of copies in single issues			
			No. 1	No. 2	No. 3	No. 4
1	1942	0	0	0	0	4
2	1943	0	14	6	0	0
9	1950	0	0	0	44	47
10	1951	0	0	89	0	40
11	1952	0	0	0	70	129
12	1953	35	55	88	73	35
13	1954	274	274	294	312	376
14	1955	53	78	95	101	53
15	1956	112	112	156	179	179

These back numbers may be purchased from the Business Manager at the following rates: Volumes 10–14, $2.00 per single copy for Domestic and $2.25 for Foreign; for preceding issues, $1.25 and $1.50 respectively. In addition, the following proceedings may be purchased at a cost of $1.00 each Domestic and $1.25 each for Foreign.

PROCEEDINGS OF THE SOCIETY

Year	No. of copies	Year	No. of copies
1915–16	47	1931	58
1922	325	1932	17
1923	240	1933	37
1925–26	44	1934	23
1927	45	1935	27
1929	29	1940	43
1930	27		

W. G. Kammlade gave the report of the Nominating Committee for A. E. Darlow. The Committee proposed the names of J. C. Miller for

President, and W. M. Beeson for Vice President. These men were elected by unanimous vote. Nominees for Secretary-Treasurer were E. R. Barrick and H. H. Stonaker. Ballots were distributed for voting by tellers, O. G. Bentley, A. L. Pope and H. S. Teague.

W. M. Beeson called to the attention of the Society the recent publication of a booklet listing the officers and editorial board, History and Purpose, Constitution, former officers, honor guests, Morrison Award winners, American Feed Manufacturers' Award winners and names and addresses of all the members. Extra copies of this booklet can be purchased from the Secretary's office for $1.00.

The report of the Committee on Research was given by G. Bohstedt:

"The Committee on Research is gratified at the presentation of the three speakers on the panel discussion of 'The Meat Type Steer', and on the way the speakers have responded in reference to suggestions as to outlining present inadequate standards and the need for research leading to a set of specifications for a desired type beef animal, both alive and in the carcass. The Committee feels strongly that the members of the Society and any others interested should be able to refer at any time to the facts and suggestions thus brought before them, and recommends to the Executive Committee and Editorial Board that the three manuscripts of the symposium be printed in the Journal of Animal Science".

Progress on the preparation of the Monograph was given by C. E. Terrill:

"The Monograph, 'Techniques and Procedures in Animal Production Research' is not yet complete. A portion of one section and some revisions on other sections are still to be done. These revisions had been postponed until all sections were complete. It is planned to submit the Monograph to the Research Committee by May 1, 1957. Mr. President, I move the adoption of this report".

The Extension group has selected the following men to prepare the extension program for the 1957 meetings: Henry P. Holman, Chairman, Jack Kelly and M. D. Lacy.

J. C. Miller thanked the Membership Committee for their fine cooperation and excellent work in obtaining new members for the Society.

Doyle Chambers stated that the Teaching Committee had no special report to make to the Society.

The report of the Committee on Information was given by Carl F. Neumann:

"As you know, the duties of the Committee on Information are designed to relay information concerning various reports presented at the meetings of the Society as well as any special events—such as the Morrison Award and the ceremonies incident to honoring the recipient of the award. In other words the Committee seeks to bring news accruing from the annual meeting to the attention of large numbers of people who do not have the privilege of attending the various sessions.

"At this time the Committee wishes to thank all those who responded promptly to our request for advance copies of the papers to be presented. This is very important because news releases—especially those going to daily papers must go out well in advance of the meeting. The wire services and daily papers will not usually make use of news items which are even a half day late.

"Now in considering the news outlets which are used in the Information phase, use is made of the radio broadcasts. News stories have already been mailed to farm radio broadcasters and commentators in the Chicago area and there is no question but that they always make good use of the news material.

"The Chicago papers are also sent news which will in our opinion, be of interest. Yesterday two of these papers—the *Chicago Daily News* and the *Chicago American* each used a story. The combined circulation of these two daily papers is around 1,250,000.

"Three press wire services are sent news stories—these include the Associated Press, the United Press and the International News Service. Each year these agencies are responsible for the use of various stories in daily papers from coast to coast—thus bringing the Society doings to millions of readers.

"Of special interest, of course, in considering outlets for information relative to the Society meetings are the publications of the livestock and meat industry.

"This year all of the country's sheep publications are receiving news releases of particular interest to them. These sheep papers are published in 7 states.

"All of the swine papers are receiving stories and they are published in 3 states.

"The livestock market papers which always make good use of all news concerning this Society's activities, and published in 10 states, are receiving all of the news releases issued.

"News releases are going out to farm papers in 13 different states. News stories are going out to cattle and general livestock papers in 21 different states.

"A quick calculation indicates that approximately 1,700 individual news releases in aggregate will have been mailed out before the work of the Committee on Information is completed.

"We can well believe that this dissemination of news material will be beneficial in calling attention to the work of the Society and to some of the results of research carried on by its members in varied fields.

"Special thanks is due to Dr. Loosli of Cornell University in making abstracts of reports available as well as for information concerning the program.

"Our thanks also to Dr. J. O. Grandstaff of the Committee for his preparation of some of the reports in news release form".

Glen Bratcher reported for the Necrology Committee and recommended that the following memorials be published in the Journal of Animal Science: Samuel Brody, W. C. Coffey, J. J. DePape, C. W. Hickman, M. P. Jarnagin, P. S. Jordan, D. J. Kays, M. H. Kerr, H. R. Kraybill, C. D. Lowe, W. L. Robison, E. L. Scott.

This report was accepted with a minute of silent prayer in remembrance of these members.

J. C. Hillier gave the following report for the Resolutions Committee:

"BE IT RESOLVED that the Membership of this Society express appreciation to Prof. and Mrs. F. B. Morrison for their continued interest and generosity in providing the Annual Morrison Award.

"BE IT RESOLVED that this Society express appreciation to the American Feed

Manufacturers Association for its continued interest in and recognition of outstanding research accomplishments of Society Members.

"BE IT RESOLVED that the Society express its appreciation to the Saddle and Sirloin Club of Chicago for their invitation to hang the portrait of our honored guest, Dr. J. L. Lush in their gallery of portraits of distinguished men.

"BE IT RESOLVED that this Society express its appreciation to the Ralston Purina Company for their interest in and support of advanced training of students in Animal Husbandry through the granting of scholarships to outstanding students.

"BE IT RESOLVED that the membership of the Society express its appreciation to the officers, the editor of the Journal of Animal Science and the editorial board of the Journal for their efforts in handling the affairs of the Society so ably during the past year. Thanks are also due to those who have served on the various committees and as special representatives of the Society to other groups.

"BE IT RESOLVED that the Society express its appreciation to the Sherman Hotel for the meeting facilities provided".

As a special representative of the American Association for Advancement of Science Council, T. C. Byerly announced that Section O of the A.A.A.S. annual meeting will feature a symposium on "Grasslands in Our National Life" at the Hotel Martinique, New York, on December 27–30, 1956. Members interested were invited to attend.

Reports on the activities of the Committee on Intersociety Cooperation and Scientific Manpower Commission were submitted in writing as follows:

"Since the second annual report given at the business meeting of this Society last year, meetings have been held on February 29, April 6, May 17 and October 31. The one in May was a joint meeting of the Engineering and Scientific Manpower Commissions and was held in New York. Reports of these meetings have been sent to your secretary.

"At the Scientific Manpower Commission Meeting in October, your representative was reelected to succeed himself for the three-year term beginning January 1, 1957. At this time it was unanimously voted 'that the exeutive director write each of the secretaries of the nominative agencies requesting that a contribution be budgeted for 1957 but indicating the commission's hope that, if industrial support continues at the 1956 level, the nominating agencies will not be asked for such sums as they may budget for commission use'.

"As an after-luncheon speaker, General Lewis B. Hershey livened up the subject of 'The Special Skills Reserve Program'. He reported that to date 2,243 applications have been received from men with special skills, and 1,244 have been approved, although only 744 are at present serving in uniform. Of the remainder, approximately 700 applications are being processed, 229 have been rejected, and upon physical examination 61 men were classified IV–F.

"Following extended discussion of an invitation from the International Science Foundation asking the Scientific Manpower Commission to become a participating member of the foundation, it was moved, seconded, and VOTED that the question be tabled without prejudice, and that the executive director obtain additional information, specifically with reference to the international composition and activities of the foundation.

"The executive director presented an invitation to sponsor the program of the recently founded Council for Basic Education by becoming 'an associated organization'. Following discussion of the nature, objectives and membership of the

council, it was moved, seconded, and VOTED that the Scientific Manpower Commission accept the invitation.

"The following is taken from a report of the Policy Committee for Scientific Agricultural Societies:

Activities of the Scientific Manpower Commission

"The SMC was instrumental in the passing of the National Reserve Act of 1955, which was the first military legislation giving due recognition to the importance of science and technology in the nation's security. The final legislation as passed by the Congress is known as Public Law 305. While it is primarily concerned with the development of a military reserve, the Executive Branch of the Government is charged with the responsibility of formulating regulations covering scientists and engineers. Regulations have been announced which will permit relaxing the age limit for volunteers (prescribed by the laws as between 17½ and 19 years of age) for engineers and scientists, who may apply for reserve status under the plan any time following their classification into I–A status.

"Scientists and engineers whose services are needed in teaching, research, and defense-supporting industries may be transferred from the ready to the stand-by reserve without regard to their remaining reserve obligations.

"A joint committee was appointed by the Scientific Manpower Commission and the Engineering Manpower Commission to make recommendations on the need for scholarships to encourage more qualified secondary school students to enter college. The two Commissions also are collaborating in a study of the needs for space, equipment and staff in college departments of engineering and science. Progressive steps must be taken very quickly if the increased student population is to be accommodated by 1958–59. A national conference on this problem has been proposed.

"The joint efforts of the Scientific and Engineering Manpower Commissions are partially responsible for the recent publication of a factual review of the scientific and technological manpower situations in the United States, Western Europe, and Russia, by the Joint Committee on Atomic Energy of the Congress. This Committee has announced the holding of public hearings to determine the magnitude of our technological manpower deficiencies and to determine what corrective measures may be required by the Congress.

"The activities of the Scientific Manpower Commission and the Engineering Manpower Commission are also partly responsible for President Eisenhower's appointment in April of a 19-man national committee for the development of scientists and engineers of which Dr. Howard L. Bevis, former president of Ohio State University, is Chairman.

"Since the establishment of the Scientific Manpower Commission in January 1953, public interest in specialized manpower needs has made steady improvement. At that time there was practically no public interest in manpower problems, whereas today actions on many fronts attest to the fact that the public is becoming more and more concerned with manpower supplies as related to our national security".

Activities of the Society for Division of Biology and Agriculture, National Research Council and Agricultural Research Institute were read by J. O. Grandstaff.

"On June 30, 1955, L. A. Maynard became chairman of the Division of Biology and Agriculture, succeeding Paul Weiss.

"The Committee on Feed Composition completed a report on Composition of Concentrate By-product Feeding Stuffs which has been released as NAS–NRC publication 449. The publication includes tables of composition of 58 nutrients for plant and animal by-products based on reviews of 3,000 published articles, together with unpublished data furnished by 184 cooperating laboratories. Data on the composition of domestic cereal grains and forages are now being compiled for publication.

"The Committee on Animal Breeding and Genetics is preparing a manuscript on fields in which research is needed and indicating what the committee considers to be the most potentially productive fields of research in animal breeding. The report is scheduled for publication in 1957.

"The Committee on Animal Nutrition reported the following progress on reports:

"1. Revision in press. Recommended Nutrient Allowances for Dairy Cattle.

"2. Being revised. Recommended Nutrient Allowances for Sheep.

"3. Being revised. Recommended Nutrient Allowances for Beef Cattle.

"4. The Committee on Horses has been reorganized and will begin revision of the report on Recommended Nutrient Allowances for Horses.

"5. Report in progress. Recommended Nutrient Allowances for Laboratory Animals.

"6. Revision scheduled for 1957. Recommended Nutrient Allowances for Poultry.

"7. Revision scheduled for 1957. Recommended Nutrient Allowances for Swine.

"8. The Committee on Hormones in Livestock Feeding has been reorganized and will soon begin collection and evaluation of new research information.

"9. The Committee on Feed Additives has been reorganized, and a report is in progress.

"10. A statement on the need for research on nutrient requirements has been prepared by the Committee on Animal Nutrition and distributed to State and Federal research administrators.

"The following additional reports of the Committee on Animal Nutrition were issued by the NAS–NRC and the sub-committees discharged.

"1. A Review of Bloat in Ruminants. Publication 388.

"2. The Fluorosis Problem in Livestock Production. Publication 381.

"The second edition of a Handbook of Laboratory Animals is being prepared by a committee of the Institute of Animal Resources for publication in a loose-leaf cover so that it may be kept current with addition and revisions of material. The book will include sections on genetics and breeding, nutrition, disease, caging, housing and sanitation. Publication of the book by NAS–NRC is scheduled for the early part of 1957. Procedures for the standardization and certification of laboratory animal suppliers are being developed for use by State and Federal agencies, and criteria for scientists to use in the procurement of laboratory animals.

"The first edition of the Handbook of Biological Data compiled by a special committee of the Division will be published at an early date by the W. B. Saunders Company. It contains about 446,000 values furnished and authenticated by 4,043 principal contributors and reviewers. An estimated 17,000 scientists have aided the handbook staff as contributors, reviewers, appraisers, or advisers. The major subject areas covered in this volume are biochemical and biophysical characteristics; genetics, cytogenetics and reproduction; development and morphology; nutrition, digestion and metabolism; respiration and circulation; other physiological activities and performances; biologically active compounds; environment and survival; symbiosis and parasitism; and ecology and biological geography. There is an extensive appendix on taxonomic identification of plants and animals. The handbook will be a valuable reference for all biologists, especially for reference on subject-matter fields that are outside an individual's immediate area of specialization.

"The newly organized Committee on Fats and Oils is giving consideration to the broad problems relating to the impact of fat consumption, production, and marketing trends as affecting the total agricultural crop and animal situation in the United States.

"The new Committee on Agricultural Equipment has prepared summaries on several problems, including the effect of materials processing in use of farm crops for livestock.

"The Post-doctoral Fellowship Committee screened 136 applications for National Science Foundation post-doctoral fellowships, of which 83 were in animal science. The recommendations of this committee go to the screening committee of the Academy Council for final recommendations to the National Science Foundation. Fellowship awards made by NSF for the fiscal year 1956 included 20 senior post-doctoral, 15 post-doctoral, and 157 pre-doctoral fellowships.

"The Committee on Fulbright Fellowships screened a total of 157 applications during the year. Grants awarded included 14 in agriculture, 4 in bacteriology, 10 in biochemistry, and 5 in zoology".

"The Agricultural Research Institute, a supporting agency of the Agricultural Board organized in 1951, provides 'a forum for unrestricted discussion of common problems by industry, public agencies, scientific societies and private institutions'. Its objectives include formulation of comprehensive policy and promotion of cooperation in the fields of agricultural sciences. Its membership consists of scientific societies, Federal research agencies, State Agricultural Experiment Stations, associations and councils, and industrial corporations. An important feature of the 1956 annual meeting was a series of three panel discussions on industry-government relationships in agricultural engineering research, plant breeding, and research support.

"Based on previous recommendations of ARI and with its financial support, the Agricultural Board has now achieved a better balance between its plant and animal science activities. The committee structure of the Board was broadened during the year with the addition of six new committees: (1) Soil and Water Conservation, (2) Soil-Crop-Water Relationships, (3) Agricultural Meteorology and Climatology, (4) Plant Breeding and Genetics, (5) Economics of Fertilizer Use, and (6) Plant Composition in Relation to Soil Nutrients. With these additions the Board now has 16 standing committees and 24 subcommittees.

"The 1956 Project and Proposals Committee continued the established policy of soliciting suggestions from all ARI members as a basis for recommending additional activities to the Agricultural Board. The proposals received in previous years which required research and therefore could not be assigned to existing committees of the Board, were summarized and given wide distribution to experiment stations and research agencies. Recommendations made to the Agricultural Board this year included the following proposals:

"(1) Establishment of an 'ad hoc' committee to consider the industrial uses of agricultural products, as an aid to the Agricultural Board in planning future activities in this area.

"(2) Establishment of an 'ad hoc' committee to investigate the needs and desires for mandatory inspection of slaughtered poultry.

"(3) That ARI, within its own structure, appoint industrial liaison committees to assist the appointed committees of the Agricultural Board in securing reference materials, gathering basic information, and possibly in raising funds to support that committee's activities. Other proposals of a suitable nature received in 1956 were referred to the appropriate standing committees of the Agricultural Board for further consideration.

"The Recruitment Committee appointed in 1955 on an 'ad hoc' basis considered problems relating to future scientific manpower, and reported the following general conclusions and recommendations:

"(1) Since the shortage of scientific manpower already is receiving much attention, the committee believes that ARI should keep fully informed of the actions of other agencies, particularly as related to the agricultural sciences, and be prepared to give support where needed.

"(2) Maintenance of quality of scientific manpower in times of present shortage requires continuous planning and rigid standards, and therefore cannot be achieved through resolutions.

"(3) Shortage of manpower results from our increasing application of science and will increase with further creativity. The efforts of ARI must be directed to further increasing this shortage by the creation of new opportunities.

"(4) With limited capable scientists available, ARI must direct its efforts through its individual members to explaining the opportunities of science to the boys and girls with whom they come in contact. Adequate financial compensation undoubtedly will aid in maintaining qualified scientists in agriculture.

"The 'ad hoc' committee appointed in 1955 to consider procedures for collecting and disseminating research information reported a number of suggestions which it believes will be useful in improving communications between agricultural scientists and between agricultural scientists and other groups:

"A second conference on Pesticide Applications and Regulations sponsored by the ARI at the request of interested groups, was held in Washington on November 15, 1956. Participation in the conference included representatives of industry, Food and Drug Administration, USDA research and regulatory branches, State Experiment Stations, and Public Health Service.

"Present membership of ARI consists of 71 class A members representing industry, and 95 class B members representing scientific societies, State Experiment Stations and Federal research agencies. This reflects an increase of 13 class A members and 7 class B members during the year.

"W. C. Dutton, Dow Chemical Company; and M. T. Goebel, E. I. DuPont & Company, were reelected president and vice president, respectively. Bert Johnson, National Cotton Council, was elected secretary".

Ralph W. Phillips, Deputy Director of Agriculture Division of F.A.O., who has served for several years as a special representative of the Society to maintain liaison with the European Association for Animal Production, submitted the following report through Roy C. Dawson, Agriculture Division of F.A.O., Washington, D. C.

"The European Association for Animal Production (EAAP) has as members national organizations in 21 countries, namely, Austria, Belgium, Denmark, Finland, France, Germany, Iran, Israel, Italy, Luxembourg, Morocco, The Netherlands, Portugal, Spain, Switzerland, Tunisia, Turkey, United Kingdom, Yugoslavia and Sweden, this last national organization having joined in 1956.

"The financial situation of the Association remains sound, all members organizations having paid their subscriptions, thus allowing the Association to meet its normal expenses.

"The Association continues to conduct its work primarily through the holding of study meetings and through study commissions set up to deal with various aspects of animal production.

"In May 1956, the Association, in collaboration with the Spanish Government, held the VIIth International Congress of Animal Husbandry in Madrid. This

was immediately preceded by meetings of the Study Commission in the various fields of animal production.

"At the Congress, attended by some 540 delegates from 44 countries, papers were given on the following subjects:

"1. 'The significance of the phenomenon of heterosis and of environmental conditions, particularly that of climate, on the quality of pig meat', by M. Odriozola of Spain; 2. 'Blood-grouping and its utilization in Animal Breeding', by M. R. Irwin (serving as FAO Consultant); 3. 'The quality of animal products in relation to the nutrition of farm livestock', by P. Saarinen of Finland; 4. 'Modern problems in the improvement of wool production', by P. Charlet of France and H. B. Carter of the United Kingdom; 5. 'Review of the present day problems posed by variations in the solids-not-fat content of milk', by R. D. Politiek of Holland; 6. 'Modern concepts of ruminant digestion and metabolism', by D. P. Cuthbertson and A. T. Phillipson of the United Kingdom; 7. 'Relation between pulling tests and physiology and anatomy of horses', by L. Krüger of Germany.

"Delegates to the Congress were also afforded the opportunity of an excursion lasting several days through Andalucia, to see breeding establishments and cross-section of Spanish livestock conditions.

"In view of the general interest shown in animal genetics, the Associations have formed a new study commission to take care of the problems in this field, in addition to the existing commissions.

"The commissions, consisting in each case of workers prominent in their respective fields in the countries from which the organizations are members of the Association, continued to give attention to a number of topics. Work has included the completion of compilation of information on pig progeny testing in the various countries; the possible standardization of methods of fodder analysis; the establishment of a method of expressing the protein requirements of domestic animals; a revision of the Index of Agricultural Research Institutes in Europe, together with an indication of their major research projects; further studies on the economic situation of horse breeding in Europe and the influence of farm mechanization; a study of the progeny testing of beef cattle and a catalogue of European breeds of cattle.

"The Association is also cooperating with FAO in the completion of a glossary of animal husbandry terms which it is hoped will be available in four languages: English, French, German and Spanish.

"The combined FAO/EAAP meeting on pig progeny testing which it had been hoped to arrange in Denmark in November 1956 has been deferred to July 1957 to allow the holding of a further preliminary meeting of the EAAP Pig Study Commission in Paris in November 1956.

"During the year the Association issued the English edition of its fourth publication 'The Production and Marketing of Meat'.

"It is hoped to hold the next series of study commission meetings in June 1957, in Luxembourg. Any members of the American Society of Animal Production who plan to be in Europe during the coming summer may wish to attend the meeting or the Pig Progeny Testing Meeting in Copenhagen in July. Information concerning the meetings sponsored by EAAP may be obtained from Dr. K. Kallay, Secretary of the European Association of Animal Production, Via Quintino Sella 54, Rome, Italy".

No report was given for the Ralston Purina Award Committee. President Casida stated that "the Society wishes to express its appreciation to the Ralston Purina Company for encouraging graduate study and development of men by these Fellowship Awards".

President Casida announced that the Society will be an affiliated member of the American Institute of Biological Sciences. The benefits from this affiliation will be published in News and Notes section of the Journal.

H. H. Stonaker, Colorado A. & M. College, Fort Collins, Colorado, was elected Secretary-Treasurer of the Society. The new officers for the Society for 1957 are: J. C. Miller, President; W. M. Beeson, Vice-President; and H. H. Stonaker, Secretary-Treasurer.

The meeting adjouned at 3:30 p.m.

Respectfully submitted,

W. M. BEESON, *Secretary-Treasurer*

MEMORIALS

Samuel Brody

Samuel Brody, Professor of Dairy Husbandry and a member of the University of Missouri staff, 1920–1956, died of a heart attack while at work August 6, 1956. Words alone cannot describe fully the greatness of his scientific contributions. His was one of the greatest minds engaged in basic research and applied science in Agriculture and the livestock industry, but his contributions covered many fields beneficial to human welfare.

He was an authority on growth, aging, metabolism, productive processes and environmental physiology of domestic animals. Recipient of many honors, his work brought world-wide recognition to himself and to the University of Missouri. He won a Guggenheim Foundation Fellowship for study in Europe, 1930–31; was the recipient of the Borden Award for Research in Dairy Production, 1950; and the National Distinguished Service Gamma Sigma Delta award, 1955. Special grants in support of his work, chief among which were funds provided by the National Research Council, Herman Frasch Foundation, United States Navy and the Atomic Energy Commission, totaled $252,000.

Brody joined the Dairy Husbandry staff of the University of Missouri in 1920 as assistant professor, became an associate professor in 1925 and was advanced to the rank of professor in 1945. He also carried similar ranks in Agricultural Chemistry. He served as chairman of the Herman Frasch Foundation for Research in Agricultural Chemistry (Dairy Husbandry Project), Missouri Agricultural Experiment Station, 1929–40; chairman of the Station Project on muscular work in farm animals since 1941; and chairman of the Committee on Influence of Climatic Factors on Physiological Reactions and Productivity in Farm Animals since 1946.

Dr. Brody was a Fellow of the American Association for the Advancement of Science; member of the American Society of Naturalists, National Research Council (member of the sub-committee on energy metabolism in relation to agriculture, sub-committee on standardization), American Association of University Professors, American Chemical Society (member, Division of Biological Chemistry), American Society of Biological Chemists, American Institute of Nutrition, American Dairy Science Association, American Society of Animal Production, Missouri Historical Society, Missouri Academy of Sciences, Czechoslovak Academy of Agriculture, Sigma XI, Gamma Sigma Delta. Clubs: University, Philosophical (Columbia, Missouri). Author of that monumental book, Bioenergetics and Growth, 1945; also chapters in several books and encyclopedias, numerous scientific papers and 100 research and Station bulletins of the Missouri Agricultural Experiment Station. Degrees: A.B., University of California, 1917, A.M. 1919; Ph.D., University of Chicago, 1928.

Samuel Brody was born in Garbatchi, near Baranowitz, Lithuania (now Poland), February 8, 1890, the son of Avram J. and S. Deborah (Malov) Brody. He came to the United States in 1906, naturalized 1912. Served with Air Service, also with Development Division of the Chemical War Service, U. S. Army, 1917–18. Assistant biochemist, University of California Medical School, 1919–20. He married Sophie Edith Dubosky, August 14, 1920. They have two children—Dr. Eugene Bloor Brody and Dr. Arnold Jason Brody.

Walter Castella Coffey

Walter Castella Coffey, president emeritus of the University of Minnesota and for 20 years Dean and Director of the University's Department of Agriculture,

passed away January 31, 1956, in an Orlando, Florida, hospital on the eve of his eightieth birthday.

Dr. Coffey was nationally recognized in agriculture as an advisor and as an inspirational counselor to leaders in farm organizations and Land-Grant colleges and to the thousands of individuals who sought his help.

Dean Coffey, as he was affectionately known to all who knew him, was born on a farm near Hartsville, Indiana, February 1, 1876. When he was eight years old he became greatly interested in sheep, chiefly because of a change from grade Leicester to grade Shropshire sheep on his father's farm. At one time, too, he served an apprenticeship of several months under Thomas Bradburn of New York, one of the greatest breeders and fitters of Shropshire sheep in America. Determining to become a breeder of sheep, young Coffey associated with his father in the production and exhibition of some outstanding Shropshires.

But he was destined to become an educator. He attended Hartsville College and Franklin College in Indiana, and the University of Indiana briefly. His enthusiasm and success caught the attention of Professor H. W. Mumford, head of the animal husbandry work of the College of Agriculture, University of Illinois, who asked him to become herdsman and shepherd of the flocks at the Illinois College of Agriculture in 1903. Very soon afterwards he was invited to teach a course in sheep husbandry. This led to his completing courses for a Bachelor's (in 1906) and a Master's degree (in 1909) at the college and to his being assigned to the supervision of the sheep husbandry courses.

In this way Dr. Coffey began 18 years of service to the University of Illinois. During this time he became professor of sheep husbandry and acting head of the department of animal husbandry. Soon he was widely known as a teacher and investigator in his chosen field, publishing numerous bulletins and papers and a textbook on "Productive Sheep Husbandry". President Taft recognized his promise early in his career at Illinois by appointing him a member of the President's Federal tariff board.

Dr. Coffey came to the University of Minnesota in 1921 as dean of the University department of Agriculture, immediately stepping into a position of leadership in northwestern agriculture, a position soon recognized by his appointment as member of a conference on agriculture called by President Coolidge.

During his 20 years as Dean of the Department, he held many important agricultural posts. By initiating action which prompted the establishment of the federal government's gigantic drouth relief program in 1934, and through the prominent part he had in carrying out this work, he became a conspicuous figure in public affairs, serving as regional director of all drouth cattle purchases. He was also a director of the International Livestock Exposition, vice president of the American Association of Land-Grant Colleges and State Universities, chairman of the Agricultural Board of the National Research Council, and chairman of the Board of Directors of the Minneapolis Federal Reserve bank.

In 1927 Dr. Coffey was honored by Hamline University with the degree Doctor of Laws. In 1942 he received the distinguished service award of the American Farm Bureau Federation. In 1943 he received an honorary D.Sc. degree from Franklin College and in 1946 the honorary D.Sc. degree from the University of Minnesota.

In 1941 Dr. Coffey was named president of the University of Minnesota, a position which he held during the troubled war years until June 30, 1945, when he retired.

Even in retirement, Dr. Coffey was active in many activities closely related not only to the welfare of agriculture but also to the entire state. Hamline University called upon him to serve as its acting president from June, 1952 to January, 1953 while a permanent president was being selected.

Later he assumed the chairmanship of the fund drive for the St. Paul Campus Student Center, a drive that will soon see its fruitful conclusion with the laying of the cornerstone of this much needed St. Paul Campus building.

In November, 1949, the Administration building on the St. Paul Campus was renamed Coffey Hall in his honor.

Dr. Coffey was a firm believer in the future of rural life built upon a sound agriculture. Besides having a professional interest in agriculture, he had that broader sympathy and understanding which comes from a life-long association with farmers and their problems.

He was a member of Sigma Xi, Sigma Alpha Epsilon, Alpha Zeta, Gamma Sigma Delta, and Phi Kappa Phi, and honorary life member of the Minnesota Horticultural Society and the Minnesota State Agricultural Society.

In addition to his membership in many agricultural organizations, Dr. Coffey was a Rotarian, a Mason, a member of the Minneapolis Club, the Campus Club, the Minikahda Club, and one of the outstanding laymen of the Methodist Church in America.

Dr. Coffey is survived by Jennie Crisler Lardner, whom he married in 1907; two sons, Lardner A. Coffey of the Mayo Clinic, Rochester, and Walter C. Coffey of Minneapolis; and four grandchildren.

Joseph J. DePape

Joseph J. DePape, born in Swan Lake, Manitoba, Canada, March 6, 1929, passed away very suddenly on Wednesday, October 17, 1956, in Seaforth, Ontario, Canada. He is survived by his wife, Evelyn and three children; Dennis, Paul, and Michelle; his mother, Mrs. Mary DePape of Norwood, Manitoba, Canada, seven brothers and four sisters.

Funeral services were held in St. Martin's Catholic Church in Swan Lake, Manitoba, Canada, and burial was in St. Martin's Cemetery, Saturday, October 20, 1956.

Joseph attended school at St. Paul's College, Winnipeg, Manitoba, Canada; University of Manitoba. He received his Master's degree at Montana State College, Bozeman, Montana, and his Ph.D. from Oklahoma Agricultural and Mechanical College in Stillwater, Oklahoma, 1954.

His death was attributed to a cerebral hemorrhage.

He was Director of Nutrition for the "Topnotch Feeds Company, Limited", Seaforth, Ontario, Canada, since July, 1954.

Cuthbert Wright Hickman

Cuthbert Wright Hickman, nationally known livestock authority, head of the Department of Animal Husbandry emeritus, died suddenly Saturday, April 21, 1956 of cerebral hemorrhage.

He was born January 22, 1888 at Marshall, Missouri. He received a Bachelor of Science degree from the University of Missouri in 1913 and a Masters degree from the University of Idaho in 1928. He began his long career at the University of Idaho in the fall of 1914. Prior to coming to the University of Idaho he was an instructor in the Animal Husbandry Department of the Pennsylvania State College where he served the school year of 1913–14.

He became head of the Animal Husbandry Department of the University of Idaho in 1918 and held that position until 1951, when he was designated as head emeritus and continued as a professor. He was assistant dean of the College of Agriculture from 1942 to 1946 and acting dean in 1946 and 1947.

In 1952 he was honored by associates and friends in the cattle industry of the West with the establishment of the Hickman Hall of Fame.

He was the first president of the Western Section of the American Society of

Animal Production. He has been national secretary of the American Suffolk Sheep Society since 1936.

He was a well-known judge of beef cattle, sheep and swine for fairs and livestock shows throughout Western United States and Canada.

He was a member of Alpha Zeta, Sigma Xi, and the American Society of Animal Production.

Milton P. Jarnagin

Milton Preston Jarnagin, retired head of the Animal Husbandry Department of the University of Georgia died August 4, 1956.

Dr. Jarnagin was born in Prince Edward County, Virginia, September 17, 1881, at the home of his mother's people. He was the son of Milton Preston and Agnes Watkins Jarnagin, who, at the time of his birth, resided in Jefferson City, Tennessee, where the early part of his life was spent.

Following his Freshman and Sophomore years at the University of Tennessee he attended the University of Wisconsin and subsequently Iowa State College, receiving his Bachelor of Science degree in Agriculture from the latter institution in 1906. Dr. Jarnagin was subsequently the recipient of two honorary degrees—the Master of Agriculture degree presented by Iowa State College in 1931 and the Doctor of Science degree presented by the University of Georgia in 1922.

His first position was on the faculty of Virginia Polytechnic Institute under the late Andrew M. Soule with whom he came to the University of Georgia in 1907. Dr. Jarnagin served as Head of the Animal Husbandry Department of the University from 1907 to 1948, a period of 41 years. Upon retiring as head of the Animal Husbandry Department he continued to serve the State's livestock industry as an Agricultural Consultant to the Board of Regents.

During his long tenure at the University of Georgia Dr. Jarnagin built an enviable reputation for himself as an authority in all fields of livestock production and held the unofficial title of dean of the State's livestock industry. He was always an enthusiastic booster of more and better livestock for Georgia and the Southeast. He enjoyed a national reputation as a livestock judge and his words of wit and wisdom made him popular both as a teacher and as a public speaker. His many contributions and accomplishments have been recognized by different groups in various ways on numerous occasions. Perhaps his greatest honor came in 1953 when his portrait was hung in the Saddle and Sirloin Club in Chicago. In addition friends and admirers of Dr. Jarnagin have on different occasions presented two portraits of him to the University and over the years he has been tendered many other honors and recognitions.

Dr. Jarnagin was a charter member of the American Society of Animal Production and for many years was an active worker in this organization. He is listed in Who's Who. He was a director of Athens Federal Savings and Loan Association and Vice-President of the General Finance and Loan Company. He was a member of the Sigma Alpha Epsilon Social Fraternity and Phi Kappa Phi Scholastic Honorary Fraternity. He was a member of the First Presbyterian Church in Athens and for several years served as a Deacon of this church.

In 1908 Dr. Jarnagin married Miss Dorothy Greve of Chattanooga, Tennessee, who survives him along with their four children, Dr. Milton P. Jarnagin, Jr., of Chincoteague, Virginia, Mrs. George Griffeth of Atlanta, Mrs. Walter Sams, Jr. of Athens and Mrs. Robin Burnet of Blacksburg, Virginia.

Philip S. Jordan

Philip S. Jordan, associate professor of animal husbandry at the West Central School and Experiment Station, passed away March 9, 1956, at Morris, Minnesota. He was born July 25, 1888 at Milbank, South Dakota.

Professor Jordan received the B.S. degree from the University of Minnesota in June, 1913. Following graduation he served as a teacher of agriculture in the public schools at Hastings, Minnesota. On July 1, 1915, he was appointed an instructor in animal husbandry at the West Central School and Station at Morris. He was associate professor at the time of his death.

During the 41 years of his service he was in charge of the animal husbandry work. In this position he conducted many experiments in the feeding, breeding and management of livestock that have been beneficial to Minnesota farmers. Thirty-two years ago he started lamb feeding experiments and has conducted one or more each year since. The fifty-first trial was completed in January, 1956. The annual Lamb Feeders' Day program associated with these trials attracts lamb feeders from many states. Professor Jordan took an active part also in the Swine Breeding Laboratory and the Dairy Breeding Project conducted by the University in co-operation with the United States Department of Agriculture.

The fine herds of Holstein and Shorthorn cattle and the flocks of Columbia and Hampshire sheep are a tribute to his skill as an animal husbandman and to his great interest in the livestock industry. He was in demand as a public speaker at livestock meetings and as a judge at county fairs.

Alumni and former students remember with satisfaction the courses given by Professor Jordan. He taught with enthusiasm the practical phases of livestock problems and a sizeable list of successful livestock producers in west central Minnesota received their first technical instruction under him. He made a fine contribution toward the improvement of the livestock industry. To the livestock projects at West Central School and the Experiment Station he gave unstintingly of his energy and from their success he gained his greatest satisfaction. In addition to his work he was active in many livestock and farm organizations as well as in civic and community affairs. He was a member of the Minnesota Livestock Breeders Association and the American Dairy Science Association. He was a long-time member of the Federated Church of Morris.

Professor Jordan is survived by his widow, Imadee F. Jordan and three sons, Philip, Jr., Donald F. and Robert M., the latter is assistant professor in animal husbandry on the St. Paul Campus of the University; and also by four brothers, a sister, his stepmother and ten grandchildren.

Donald J. Kays

Donald J. Kays, Professor Emeritus of Animal Science, died in University Hospital November 13, 1956.

Professor Kays was born September 11, 1886, on a large general livestock farm in Illinois. From the neighboring one-room country school he went on to high school at Henry, Illinois. The next step in his ladder of education was the Northern Illinois Normal School at De Kalb where he participated in football, baseball, basketball and track. After a teaching career at Rockford High School, he operated the home farm for two years prior to enrolling at the University of Illinois.

Following his graduation from the University of Illinois he came to Ohio State as an instructor in Animal Husbandry. He rapidly advanced to a full professorship and in 1940 was named chairman of the Department, a position he filled with distinction until 1951. At that time, he asked to be relieved of administrative responsibilities so he could devote his time to teaching and writing. In 1953, he requested and received an Emeritus status.

For many years, Professor Kays taught horse and sheep production courses and coached the livestock judging team. His judging teams were first at The International Livestock Exposition at Chicago in 1921, 1932, 1933, 1939 and 1946 and at the American Royal Livestock Show at Kansas City in 1930, 1932, and 1933.

Known throughout America as a sterling livestock judge, Professor Kays has judged horses or beef cattle at all of the major shows in the United States and a number of times he has made the placings at leading saddle horse shows in Canada. He also served for many years as the secretary of the Ohio Percheron Breeders' Association and the Ohio Belgian Breeders' Association.

He was a prolific writer contributing articles to livestock and general farm magazines. But he is best known for his recent book, "The Horse", which is acknowledged as the finest treatise on that subject today. It is widely used as a textbook and is known as the horseman's Bible. His other book, an anthology, is "A Horseman's Scrapbook in Verse and Prose".

As a teacher, Professor Kays was outstanding and he has many devoted students all over America. Each Christmas he remembered more than two hundred of them with either a letter or a card. In the classroom, he was a perfectionist, never losing an opportunity to relate first-hand experiences to clinch his points. Thousands of students who came under his tutelage felt the impact of his dynamic personality and were challenged to observe and think.

Professor Kays was a reconteur of note. He made nearly 1,000 speeches during his tenure at Ohio State, most of them before agricultural groups or at livestock breeders meetings and he was much in demand as a toastmaster. Often, he was referred to as the master showman, a title which he richly deserved for no one was more competitive.

His many services to the University outside the classroom were as a member of the Athletic Board, Board of Control of the Faculty Club, Stadium Building Committee, Y.M.C.A. Board, Ohio Union Board of Overseers, College Committee on Instruction and the Entrance Board.

Professor Kays was a Mason, and belonged to Alpha Delta Phi, Alpha Zeta, Phi Kappa Phi, and Gamma Sigma Delta fraternities. He also was a long-time member of the American Society of Animal Production and at one time chairmaned the Teaching Section of this society.

Last May his Alma Mater honored him by hanging his portrait in the Department of Animal Science Hall of Fame at the University of Illinois.

Malcolm H. Kerr

Malcolm H. Kerr, who for the past nine years has been a member of the University of Maryland, Animal Husbandry Department, died of a rare kidney disease on the afternoon of May 16, at the National Institute of Health, Bethesda, Maryland.

Professor Kerr was born at Postville, Iowa, November 7, 1901. He graduated in Animal Husbandry at Ames, Iowa in 1925 and received his Master's degree from that College and later took graduate work at the University of Minnesota. Mr. Kerr worked in various fields of Animal Husbandry, serving at the Missions School at Marion, Alabama, the Navajo Indian School at Ganado, Arizona, as 4-H Club Agent in Lee County, Iowa and in the Animal Husbandry Departments of Berea College, University of Connecticut and University of Tennessee. During his last year at the University of Maryland, he spent six months as Swine Extension Specialist in British Guiana.

Professor Kerr is widely known in livestock circles throughout the United States, having judged at many of the leading Swine Shows and served as Vice President of the National Block and Bridle Club.

He is survived by his wife, Mrs. Esther Kerr; two sons, Burton and David; a daughter, Janet, and a granddaughter, all of Hyattsville, Maryland; a sister,

Mrs. H. E. Benson of Marshalltown, Iowa and a brother, Kenneth of Postsville, Iowa.

Mr. Kerr was a member of the Riverdale Presbyterian Church of Hyattsville, Maryland, where he served as deacon and elder.

Henry Reist Kraybill

Henry R. Kraybill, Vice President and Director of Research and Education of the Foundation and Director of the Department of Scientific Research of the American Meat Institute, died Sunday, September 30, at Billings Memorial Hospital on the University of Chicago campus.

An outstanding biochemist, an able administrator, and a careful and conscientious teacher, Dr. Kraybill devoted his life to the finding of new facts and the application of these findings for the improvement of some phase of agriculture. His contributions to scientific knowledge and to improvement of processes in the meat packing and allied industries have been many and important.

The zenith of public recognition of Dr. Kraybill's professional accomplishments was reached during the period of his illness. On June 3, Purdue University paid special tribute to his accomplishments by conferring on him an honorary degree of Doctor of Science "in recognition of . . . his distinctive achievements as a scientist, teacher and administrator whose contributions to biochemistry, plant production, and food processing have advanced the science of agriculture with resulting benefit to all".

On September 20, he received notification that he had been designated as the recipient of the 1956 Dodge and Olcott Award in recognition of scientific accomplishments of outstanding and lasting significance in connection with the processing of meat and meat products. This recognition specifically related to the development by Dr. Kraybill and his associates at the American Meat Institute Foundation of anti-oxidants (butylated hydroxyanisole and butylated hydroxytoluene) for lard and other meat fats.

Dr. Kraybill received his Bachelor of Science Degree from Pennsylvania State University and his Master of Science Degree and Doctor of Philosophy Degree from the University of Chicago, the latter in 1917. His long professional career included positions as professor and head of the Department of Agricultural Chemistry at the University of New Hampshire, and professor and head of the Department of Agricultural Chemistry at Purdue University, as well as scientific appointments at Boyce Thompson Institute and in the United States Department of Agriculture.

Dr. Kraybill joined the staff of the American Meat Institute in 1941, as Director of the Department of Scientific Research and in the same year was appointed professor-lecturer in the Department of Biochemistry of the University of Chicago. When the American Meat Institute Foundation was established in 1947, he was appointed Director of Research and Education and, in 1955, was elected a Vice President of the Foundation.

Dr. Kraybill was a member of numerous scientific and honorary societies, many of which he had served as a national or local officer. Despite the honors received by him and his acknowledged status as a scientist and research administrator, Dr. Kraybill remained modest, unassuming and sincere. He will be remembered by his many friends, associates and former students for his sound advice, stimulating encouragement and friendly, sincere interest in their problems and welfare.

C. D. Lowe

C. D. Lowe, retired Extension Animal Husbandman of the U. S. Department of Agriculture, died December 23, 1955, from the results of a stroke suffered a month earlier.

A veteran of 26 years of service as Extension Animal Husbandman for the Federal Extension Service and the Bureau of Animal Industry of the Department, Dr. Lowe retired from active duty on June 30, 1951.

Born on a farm in Fairfield County near Tarlton, Ohio, on December 14, 1883, Dr. Lowe contributed a lifetime of distinguished service to the betterment of the Nation's livestock industry and agriculture, which made him a familiar figure in every State in the Union. He was graduated from Ohio State University in 1910 as a Doctor of Veterinary Medicine. During the next two years he served as an instructor in animal husbandry and veterinarian at the Pennsylvania State College. During 1911 and 1912, he served as a veterinary inspector for the Bureau of Animal Industry of the Department in the eradication of sheep scab in the West. From 1912 to 1914, he was livestock development agent for the Southern Railway and for the next three years, beef cattle specialist for the University of Tennessee and the Department of Agriculture, with headquarters at Knoxville, Tenn. From 1917 to 1921, he was field representative of the American Aberdeen Angus Breeders Association for the entire South and in 1922 and 1923, was State Veterinarian for Tennessee, from which work he returned to the Bureau of Animal Industry in cattle tick eradication in South Carolina, Georgia, and Arkansas, in foot-and-mouth disease eradication in New Jersey, and as extension animal husbandman, the position from which he eventually retired.

Dr. Lowe served as an expert judge at many purebred and market livestock shows throughout the country and for many years was a prolific writer and contributor to the leading agricultural and livestock press, being particularly effective in popularizing the results of complicated livestock research for practical application to the livestock production problems of the farm and ranch. He served for many years as a member of the National Livestock Loss Prevention Board, as a member and former chairman of the Public Relations Committee of the American Veterinary Medical Association and as a member of the National Brucellosis Committee. He was a member of the Alpha Psi Fraternity, the American Association for the Advancement of Science, the American Society of Animal Production, the U. S. Livestock Sanitary Association, the District of Columbia Veterniary Medical Association, the National Association of Federal Veterinarians, the American Veterinary Medical Association, and other professional societies.

On May 15, 1951, Dr. Lowe was awarded the Superior Service Award of the Department of Agriculture for his exceptional understanding, ability, and leadership in fostering and developing a cordial, effective relationship between the veterinary profession and the various educational institutions; for blending that cooperative attitude with research results as he made them available to breeders, livestock producers, marketing agencies, and meat packers; and for pioneering practical, healthy, effective meat production as the goal of all members of the livestock industry.

Dr. Lowe is survived by his widow, the former Nora Mae Anderson of Georgia, who for many years has been a leader in numerous civic and welfare activities in Washington and now resides at 3429 Oakwood Terrace, N.W., Washington, D. C. He is also survived by two children, Major Ralph W. Lowe of Levittown, Pa., instructor in R.O.T.C. at Princeton University, and Mrs. Louis W. Berger of Bethesda, Md., by five grandchildren and five sisters.

Wayne L. Robison

Wayne L. Robison passed away at his home in Wooster, Ohio, on August 18th, 1956, after an illness of several months. His passing ended a career of 40 years at the Ohio Agricultural Experiment Station.

He was born in Greenwood, Indiana, February 19th, 1891. He received the B.S. degree at Purdue University and the M.S. degree at The Ohio State University. "Robby" as he was known to his associates came to the Ohio Agricultural Experiment Station in 1915 and served continuously until his death. His research was in swine breeding, nutrition and management. He was a conscientious and productive worker and in 1947 he received the Morrison Award in recognition of his outstanding work in swine research.

He prepared the results of his research for publication regularly and published over 65 Station Bulletins and articles in Station publications. He also wrote many articles for farm papers, trade journals and scientific journals.

He was married in 1922 to Ruth Vivian Bloxham. Mrs. Robison, a daughter Joyce Elaine (Mrs. Jack Geier) and a son, Ward Lewis, survive. He is also survived by his mother, Mrs. L. D. Robison, of Greenwood, Indiana, four brothers and a sister.

"Robby" was a member of the Wooster Rotary Club and an active member and an elder in the Central Christian Church of Wooster.

Last Spring, after it became known that "Robby" was ill, he was presented with a purse from his many colleagues and his friends in the livestock industry of Ohio. The fund was to be used for travel and "Robby" with his wife, daughter and two grandchildren, enjoyed a trip to Florida.

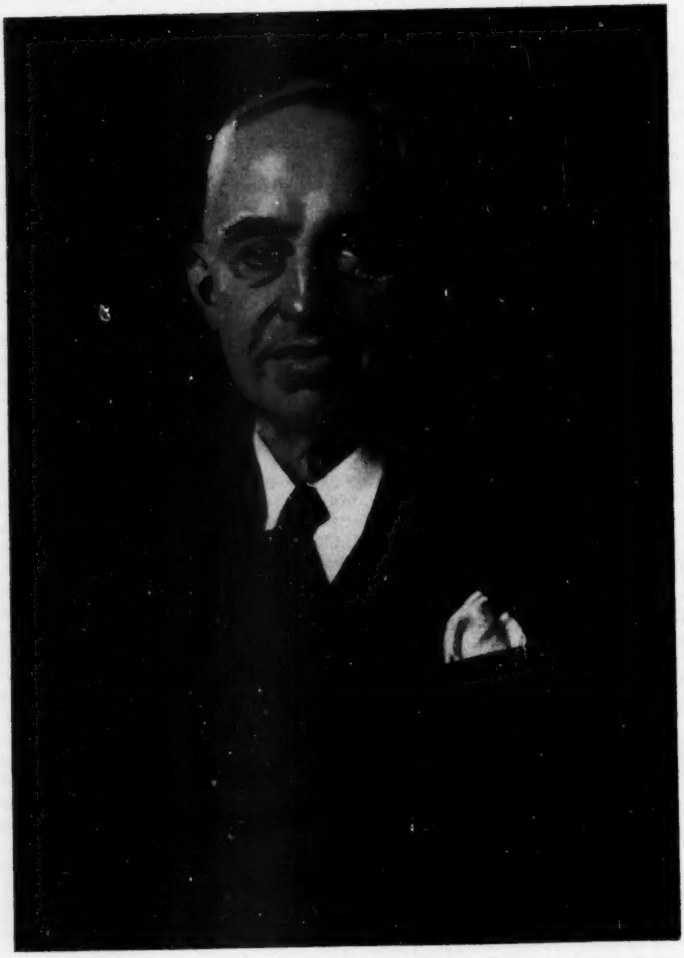
Everett Lee Scott

Everett Lee Scott succumbed to a heart attack in Phoenix, Arizona, September 11, following an illness of several months. Lee Scott, or "Scotty" as he was familiarly known to a host of friends in the livestock industry and academic circles, was born at Mineral Wells, Texas, November 18, 1896. He graduated successively from Colorado A and M and Iowa State Colleges and immediately joined the staff of the Animal Science Department, University of Arizona, in 1924. After two years he entered Purdue University where he was granted the doctorate degree in 1930. He then returned to Arizona where he served on the staff of the Animal Science Department for six years, during which time he was primarily instrumental in initiating and developing a highly successful beef cattle improvement program in Arizona, and simultaneously rendered superlative service as a teacher and research worker in the fields of animal breeding and nutrition.

Dr. Scott terminated his academic career in 1936 to join with three associates in forming the Western Farm Management Company in Phoenix, which is still active and serves a large clientele. His versatile talents and tireless energy enabled him to establish the Suncrest Hereford Ranch, one of the outstanding herds of Hereford cattle in America. He served successively as president of the Arizona, Colorado, and the American Hereford Associations.

His scrupulous conduct in all of his undertakings and intelligent understanding of the beef cattle industry brought renown to himself and the Hereford breed. He will be remembered especially by the many newcomers in the Hereford business and school and University student visitors to whom he gave generously of his time and helpful advise.

He is survived by Mrs. Scott and a son, Robert. Another son, Lt. Oliver L. Scott, was lost in action during World War II. Two grandchildren, three brothers and three sisters also survive.



DR. JAY L. LUSH

HONOR GUEST

1956

Jay L. Lush began to study animal breeding in 1914. The early enthusiasm over applying Mendel's newly rediscovered laws directly to farm animals was then beginning to be tempered by the mounting evidence that the genes were many and that their interactions with each other and with environmental differences were often complex and unexpected. Coming into the field at this stage, he became a leader among those who developed methods of uniting the sciences of genetics and biometry and of applying these methods to improving the complex productive characters of livestock.

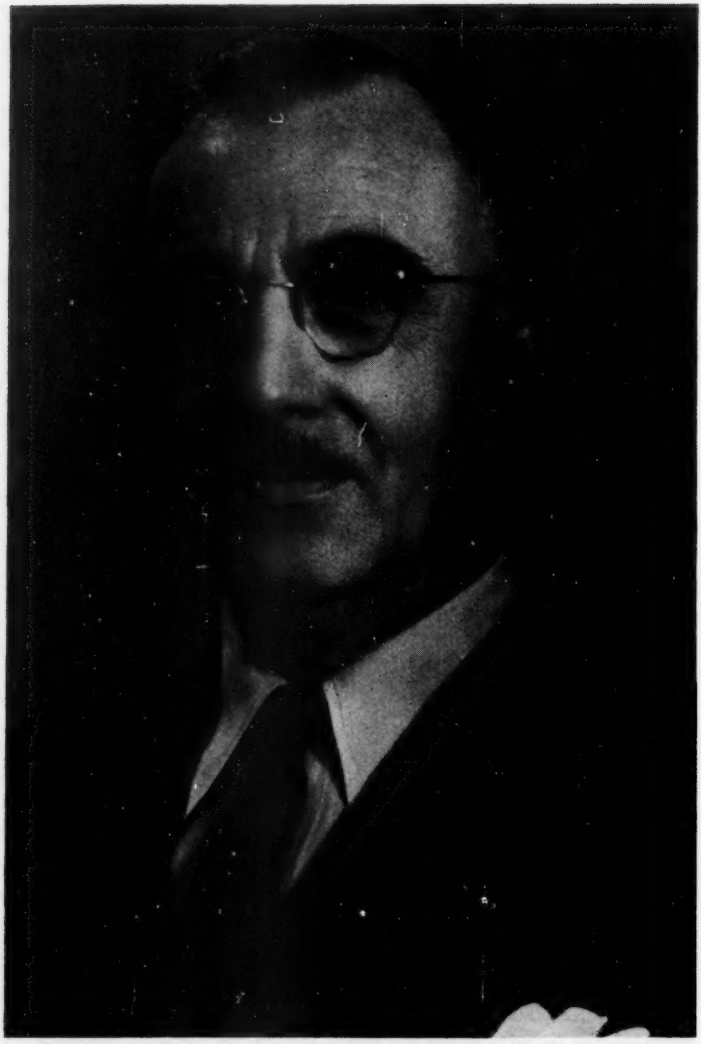
His own researches have contributed much to the concepts implied by new terms such as "heritability", "repeatability", "genetic correlation", "selection indexes", "overdominance" and "genetic-environmental interactions". Author of more than 120 scientific publications and a text, Animal Breeding Plans, Dr. Lush has dealt with a wide variety of problems, the solutions of which are basic to scientific understanding of animal husbandry problems. These include Mendelian defects of livestock, changes in form with fattening, heritability of productive characters, mating systems, heterosis in swine, consequences of selection, family selection, progeny testing, and inbreeding in swine and dairy cattle.

Known widely for his ability as a teacher, he is a leader in a school which attracts graduate and postdoctoral specialists from many countries. He never permits a busy schedule to reduce the personal contact and individual attention so necessary in the training of good scientists.

He has served as counselor for many industries. Age correction factors, requirements for progeny testing, methods of combatting dwarfism, and inheritance of resistance to mortality in poultry are examples of the problems for which associations and many private breeders have sought his advice.

His contributions to scientific agriculture in other countries include an analysis of the Danish swine progeny testing system, a series of lectures in Brazil and India, surveys of genetics and animal husbandry in Great Britain, Australia and South America.

A native of Iowa, he received his B.S. and M.S. degrees at Kansas State College in 1916 and 1918, respectively, and his Ph.D. degree at the University of Wisconsin in 1922. He was Animal Husbandman at the Texas Agricultural Experiment Station from 1921 to 1930. He has been Professor of Animal Breeding at Iowa State College since 1930. He served the society as Secretary from 1935 through 1937, as Vice President in 1938 and as President in 1939. He received the first Morrison Award in 1946. Currently he is serving on the Agricultural Board of the National Research Council and on the advisory committee on genetic research for the Atomic Energy Commission and has just completed a year as Vice President of the Genetics Society of America.



DR. WILLIAM E. PETERSON

William E. Peterson received the eleventh Morrison Award which was presented during the 48th Annual Meeting of the American Society of Animal Production in Chicago on November 24, 1956.

THE MORRISON AWARD

1956

The life story of our 1956 Morrison Award winner is that of the country boy who made good. Born at Pine City, Minnesota, he attended the University of Minnesota where he earned the B.S. degree in 1916 and the M.S. degree in 1917. From 1917–1920 he was dairy specialist at Kansas State College. He was field secretary for the Minnesota Holstein Friesian Association from 1920–21. He returned to his Alma Mater as assistant professor of dairy husbandry in 1921, and in 1928 he was awarded the Ph.D. degree by that institution. He has held the rank of Professor in the dairy department of the Institute of Agriculture at the University of Minnesota since 1940.

Although broad in scope, his research has been directed more particularly toward milk secretion and the problems therein. His earliest major contributions include a refinement of the Babcock test, and a study of artificially induced hypo-glycemia and hypo-calcemia and their relation to milk fever. His studies on mastitis led to management practices and milking techniques which have saved the dairy industry millions of dollars. His fundamental research on the "letting down" process in milk production has meant much to dairymen.

Research on the mode of synthesis of milk constituents by the mammary gland involving the development of the profusion technique, the use of the mechanical heart and lung, and control of blood pressure, by this scientist represents one of the greatest contributions to dairy science.

His latest contribution to animal science has been the rediscovery of antibody production by the mammary gland. This, together with the principle established that antibodies are absorbed through the intestinal wall, and could possibly give protection against specific maladies, may well become his greatest scientific contribution.

He is author or co-author of more than 130 technical papers, scores of popular articles and four books. He has been invited to lecture in many parts of the world, and throughout the United States and Canada.

It is a distinct pleasure to present the 1956 Morrison Award Winner —Dr. William E. Peterson.

DR. RICHARD W. LUECKE

Richard W. Luecke was given the ninth Feed Manufacturers Association Award which was presented during the 48th Annual Meeting of the American Society of Animal Production in Chicago on November 24, 1956.

AMERICAN FEED MANUFACTURERS AWARD

1956

The recipient of the American Feed Manufacturers Award for 1956 is a man who has applied his fundamental training in biochemistry to the solution of problems in the nutrition of large animals. He believes in the team approach as a means of attacking research problems, having worked cooperatively with technically trained persons in many different fields.

His contributions to the field of animal nutrition have been many and noteworthy. Although known primarily for his work in swine nutrition, his interest and enthusiasm for all facets of animal nutrition have resulted in cooperative research in many areas of both ruminant and nonruminant nutrition. In the field of swine nutrition his research has been particularly productive in relating certain enteric disturbances in weanling pigs to nutrient factors, and in establishing the B vitamin needs of the young pig. He early recognized the merits of the young pig as an experimental animal.

Richard William Luecke was born in St. Paul, Minnesota, July 12, 1917. He received the B.A. degree in Chemistry from Macalester College, St. Paul, in 1939, and later obtained from the University of Minnesota both the M.S. degree (1941) and the Ph.D. degree (1943) in the field of Biochemistry.

Dr. Luecke was an assistant at the University of Minnesota from 1941 to 1943 where he was associated with Dr. L. S. Palmer. From 1943 to 1945 he served as Biochemist at the Texas Agricultural Experiment Station at Texas A. & M. College and in 1945 he joined the staff at Michigan State University as Professor of Agricultural Chemistry, the position he now holds.

His accomplishments and contribution to the nutrition field are attested to by some 58 publications in the scientific literature beginning in 1944. He is a member of several scientific organizations and is currently a member of the subcommittee on Swine Nutrition of the National Research Council.

CHAIRMEN OF COMMITTEES, PROGRAM CHAIRMEN AND SPECIAL ASSIGNMENTS FOR 1957

Standing Committees

Committee on Research	E. J. Warwick
Committee on Monograph	C. E. Terrill
Committee on Teaching	L. E. Washburn
Committee on Extension	H. P. Holzman
Committee on Membership	W. M. Beeson

Special Committees

Committee on Information	C. F. Neumann
Committee on Necrology	G. W. Litton
Committee on Nominations	J. I. Miller
Committee on Morrison Award	W. M. Beeson
Committee on American Feed Manufacturers Award	U. S. Garrigus
Committee on Registration and Facilities	T. W. Perry

Program Committees

Breeding and Genetics	J. E. Legates
Extension	H. P. Holman
Meats	A. M. Pearson
Nutrition, Non-Ruminant	L. E. Hanson
Nutrition, Ruminant	L. S. Pope
Pastures and Forages	G. A. Branaman
Physiology	R. M. Melampy

Special Representatives

American Association for Advancement of Science Council	T. C. Byerly
Committee on Intersociety Cooperation and Scientific Manpower Commission	J. E. Foster
Division of Biology and Agriculture, National Research Council and Agricultural Research Institute	J. O. Grandstaff
European Association for Animal Production	R. W. Phillips
Ralston Purina Award Committee	R. F. Cox

NEWS AND NOTES

Allen D. Tillman, associate professor of Animal Husbandry at Oklahoma A and M College is on leave of absence and is spending one year at the University of Tennessee-Atomic Energy Commission Agricultural Research Program. He will be engaged in research concerning calcium and phosphorus metabolism in ruminant animals.

D. E. Brady is on leave from the University of Missouri and with the Livestock and Meat Products Division, Foreign Agricultural Service, United States Department of Agriculture, Washington 25, D. C.

D. M. Kinsman, former Farm Manager at the University of Massachusetts, has joined the Animal Industries staff at the University of Connecticut as Assistant Professor of Meats.

John M. Kays, formerly on the staff at the University of Missouri, joined the Animal Industries Department at the University of Connecticut as Assistant Professor in charge of the light horse program.

Kenneth A. Tabler, recently left the Department of Dairy Science, University of Illinois, where he had been employed as a cooperative agent of the Dairy Husbandry Research Branch, to join the Biometrical Services of ARS, Beltsville, Maryland.

The joint meetings of the Western Section of the American Society of Animal Production and Western Division of the American Dairy Science Association will be held on the campus of the State College of Washington, Pullman, on July 14–17, 1957.

The American Meat Institute Foundation, Chicago, Ill., has announced the appointment of B. S. Schweigert as Director of Research and Education to replace the late H. R. Kraybill. D. M. Doty and C. F. Niven, Jr., were appointed Associate Directors of Research and Education.

The fourth Southern Regional Graduate Summer Session in Statistics will be held from June 12–July 20, 1957 at the Virginia Polytechnic Institute, Blacksburg, Virginia. The sessions will be of particular interest to (1) research and professional workers who want intensive instruction in basic statistcal concepts and who wish to learn modern statistical methodology, (2) teachers of elementary statistical courses who want some formal training in modern statistics, (3) prospective candidates for graduate degrees in statistics, (4) graduate students in other fields who desire supporting work in statistics, and (5) professional statisticians who wish to keep informed of advanced specialized theory and methods.

Each annual summer session lasts six weeks and each course offered carries approximately five quarter hours of graduate credit. The program may be entered at any session, and consecutive courses will be offered in successive summers. The work in statistics may be applied towards residence requirements at any one of the cooperating institutions, as well as certain other institutions, in partial fulfillment or residence requirements for graduate degrees.

In addition to staff members from V.P.I. the faculty will include Evan J. Williams, Principal Research Officer, Commonwealth Scientific and Research Organization, Division of Mathematical Statistics, Melbourne, Australia; Daniel B.

DeLury, Director of Statistics, Ontario Research Foundation, Toronto, Canada; and J. L. McHugh, Director, Virginia Fisheries Laboratories.

Inquiries should be addressed to Boyd Harshbarger, Head, Department of Statistics, Virginia Polytechnic Institute, Blacksburg, Virginia.

Formation of a Section of Animal Behavior and Sociobiology. At a recent meeting of the Ecological Society of America at Storrs, Connecticut, a Section of Animal Behavior and Sociobiology was organized. The purpose of this Section is to advance, coordinate, and assist research and publications on the subject of animal behavior and social organization basic to theoretical science and human welfare, and to act as a liaison agency between workers in the various scientific fields concerned. The Section elected the following officers: Chairman, Dr. J. P. Scott, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine; Vice-Chairman, Dr. A. M. Guhl, Kansas State College, Manhattan, Kansas; Secretary, Dr. M. W. Schein, Pennsylvania State University, University Park, Pennsylvania. The Section immediately concerned itself with three major problems in the field of behavior studies: publications, terminology, and teaching. Persons interested in any phase of animal behavior studies are invited to become members. Further information can be obtained from the secretary.

The Ninth Pacific Science Congress will be held in Bangkok from 18 November to 9 December 1957, under the auspices of the Government of Thailand and the Science Society of Thailand. Chairmen of sections of greatest interest to animal production include: Luang Suwan Vajok Kasiky, Kasetsatr University, Bangkhen, Bangkok, Thailand, animal improvement in the Pacific area; and L. A. Maynard, Cornell University, Ithaca, N. Y., U.S.A., Pacific nutrition. Further information may be obtained from the above chairmen or from Harold J. Coolidge, Pacific Science Board, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

H. O. Kunkel was selected the outstanding professor in the school of agriculture at Texas A & M for 1956 and received a Faculty Distinguished Achievement Award of $1,000 for outstanding performance in teaching research and student relations.

R. A. Long, former Assistant Professor of Animal Husbandry at the University of Kentucky, resigned in December to accept a position as Chairman, Division of Animal Science, University of Georgia.

R. H. Dutt, Associate Professor of Genetics at the University of Kentucky, will spend the year 1957 as a Fulbright Scholar in New Zealand doing research in sheep reproduction.

E. C. Simpson has accepted a position as Assistant in Genetics at the University of Kentucky and will carry on the research projects of Dr. R. H. Dutt during the calendar year 1957.

Dana Saylor, a graduate of Oklahoma A & M College, has accepted a position as Assistant in Animal Husbandry at the University of Kentucky.

John W. Stroud has accepted a position as Assistant Professor of Animal Nutrition at the University of Kentucky beginning February 1, 1957.

On November 1, O. D. Butler became Head of the Department of Animal Husbandry in the Texas A & M college system. He succeeds J. C. Miller who is now Dean of the School of Agriculture at Texas A & M.

T. Donald Bell, Professor of Animal Husbandry at Kansas State College, has accepted a position as Head of the Department of Animal Husbandry at the

University of Idaho, effective February 1, 1957. In the new position he succeeds Carl F. Sierk, who resigned early in 1956 to become Assistant Chief of the Animal and Poultry Branch of International Cooperation Administration, Washington, D. C.

W. A. King, Professor of Dairy Husbandry, Clemson Agricultural College, Clemson, South Carolina, is the new chairman of the National Joint Committee on Grass Land Farming.

J. B. Fitch who retired June 30, 1956 as Head of the Department of Dairy Husbandry, University of Minnesota, is now head of the Dairy Science Department of the University of Arizona.

Ross Christian, former member of the Animal Husbandry Department at Washington State College, is now Assistant Professor of Animal Husbandry at the University of Idaho.

James L. Cason who recently received the doctor of philosophy degree at North Carolina State College was appointed Assistant Professor in the Animal Industry Department. He succeeds Bruce R. Poulton who has joined the Animal Husbandry staff at the University of Maine.

Carroll H. Ramage received his Ph.D. at Rutgers University last June and will continue as a member of the Dairy Husbandry Staff with the rank of Assistant Professor. He is stationed at the Rutgers Dairy Research Farm, Beemerville, New Jersey.

B. R. Baumgardt is studying for the degree of doctor of philosophy at Rutgers University and holds the rank of Instructor in Dairy Husbandry. He succeeds Frank Wright who has transferred to the Extension Service as Assistant Specialist in Dairying.

THE NEED FOR AN EXPANDED RESEARCH PROGRAM ON THE QUANTITATIVE NUTRIENT REQUIREMENTS OF DOMESTIC ANIMALS

Committee on Animal Nutrition, Agricultural Board, Division of Biology and Agriculture, National Academy of Sciences—National Research Council

In order to feed animals adequately and efficiently, a knowledge of the quantitative requirements for all nutrients is essential. This is particularly important in periods of great national stress, such as war or acute feed shortages caused by drought. Accordingly, during World War II the Committee on Animal Nutrition of the National Research Council undertook, along with its other activities, the development of feeding standards for domestic animals. These were designed to include the quantitative requirements for minerals, vitamins, and amino acids as well as for protein and energy, the nutrients which previous standards commonly covered.

At that time it was known that many gaps existed in the knowledge of the quantitative nutrient requirements of domestic animals. Much of the available information also was not as reliable as needed, because of insufficient corroboration and either failure to give proper attention to the effect of nutrient interrelationships on quantitative requirements, or lack of knowledge at the time the work was done that such interrelationships exist. These conditions proved to be a severe handicap in the development of tables of quantitative nutrient requirements.

The amount of research work on quantitative nutrient requirements which has been conducted since the end of World War II has been quite limited. Almost as many gaps in our knowledge of the subject exist now as then. Moreover, improve-

ments in feed efficiency in some instances have led many people to question the quantitative requirements determined on less efficient rations. Thus, there is a great need for an enlarged program of research by the agricultural experiment stations and their animal nutritionists and biochemists on the quantitative nutrient requirements of domestic animals, especially under conditions which permit maximum growth and production. Much more research is also needed on the effects of the environment and of the mineral content of drinking water on nutrient requirements.

More accurate and more detailed information is also needed on the nutrient composition of feedstuffs, their variability in nutrient content, and the effect of processing and storage on the stability and availability of nutrients. Routine analyses for protein, fat, nitrogen-free extract, fiber, and ash are no longer sufficient for the formulation of rations adequate in known nutrients. Information on the content of amino acids, vitamins, and essential minerals is also necessary. Finally, greater emphasis should be placed upon a study of the carbohydrate components of feedstuffs, especially lignin, cellulose, hemicellulose, and starch.

At present, few animal nutritionists are conducting any great amount of research work on the quantitative nutrient requirements of domestic animals. This is difficult to understand, since work of this character is basic research frequently requiring study of interrelationships of nutrients and of function before accurate estimation of requirements can be made. Work on quantitative requirements can lead, therefore, to new discoveries, and thus may be as pioneer in nature as research designed to reveal findings that are purely qualitative.

The Committee on Animal Nutrition expects to continue to prepare and release through the National Research Council reports giving the quantitative nutrient requirements of domestic animals. The reports already published will be revised whenever sufficient new information justifies this. Recent revisions, however, have been quite modest in most instances because of a lack of a broad research program in this country dealing specifically with the determination of these requirements.

A list of the reports on the quantitative nutrient requirements of domestic animals published by the National Research Council is given in the Appendix. A number of these reports have passed through several revisions and one dealing with the quantitative requirements of laboratory animals is in preparation. The reports have been widely distributed and have been generally used in teaching courses in animal nutrition, in preparing formulas of animal rations, and by the feed industry as a guide in the manufacture of commercial rations. The value of the reports to the livestock industry, according to information supplied the Committee on Animal Nutrition, has been exceedingly great in spite of their limitations.

In calling attention to these reports, the Committee on Animal Nutrition hopes to stimulate more interest in research on the quantitative aspects of animal nutrition, and thereby make it possible to produce needed livestock products more efficiently and more economically. The Committee on Animal Nutrition, however, can only lend encouragement to this work, as the National Research Council does not have funds with which to support research work except when specific grants are made to the Council from outside sources. On the other hand, the Council can and does obtain the assistance of American scientists in rendering advice and counsel, on request, to governmental and private agencies on special problems requiring an unbiased interpretation of the available research evidence. The reports giving the quantitative nutrient requirements of domestic animals were prepared in compliance with requests for this information in a reliable summarized form.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, double-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsiblity for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts." *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest to members. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. J. K. Loosli, Department of Animal Husbandry, Cornell University, Ithaca, New York, or to the publishers: Boyd Printing Company, 372–374 Broadway, Albany 7, New York.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. H. H. Stonaker, Department of Animal Husbandry, Colorado A&M College, Fort Collins, Colo., or to the publishers, Boyd Printing Company, 372–374 Broadway, Albany 7, New York.